Testing the Reinforcer Pathology Theory: A New Insight into Novel Targets for Drug Addiction

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ABSTRACT

Despite decades of effort developing evidence-based treatments, drug addiction remains one of the most problematic and enduring public health crises. Developing a new generation of theoretically-derived interventions constitutes an important clinical and scientific gap that if addressed may open innovative treatment opportunities. Based on the Reinforcer Pathology theory, altering the temporal window over which reinforcers are integrated (i.e., measured by delay discounting) would alter drugs valuation and consumption. The first investigation—in 2 separate studies— test the Reinforcer Pathology theory by examining the effect of expanding and constricting the temporal window of integration using two mating narratives (long-term and short-term relationships, respectively) on cigarette valuation among cigarette smokers. The second investigation, test the Reinforcer Pathology theory by assessing the effect of remotely delivered Episodic Future Thinking (EFT) narratives (expands the temporal window) on real-world alcohol consumption among individuals with alcohol use disorder (AUD). Together, these investigations supported the Reinforcer Pathology theory and demonstrated its relevance for understanding and intervening in addiction. The current findings provide scientific justification to further investigate Reinforcer Pathology based interventions that expand the temporal window to change drug valuation and consumption. The construction of multi-component treatments that incorporate Reinforcer Pathology based interventions to systematically alter the temporal window may provide a novel intervention to reduce alcohol consumption.

Keywords: Reinforcer Pathology, addiction, health risk behaviors, episodic future thinking, mating, narrative theory

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GENERAL AUDIENCE ABSTRACT

The following studies provide evidence that altering the temporal widow (how far in the future one can imagine and integrate into the present) would alter drugs valuation. In the following studies, we used narratives describing long-term or short-term mating relationships (Study 1) and Episodic Future Thinking (EFT; represents one's capability to pre-experience the future; Study 2) to alter valuation of cigarettes and alcohol, respectively. In the first study, cigarette smokers who read and vividly imagined long-term romance relationship narrative (expands the temporal window) valued cigarettes less than control (imagined looking for a lost key). In contrast, those who read and vividly imagined a short-term sexual rencounter (shortens the temporal window) valued cigarettes more than controls. The second study employed EFT (expands the temporal window) as a strategy to reduce alcohol consumption, in real-world settings, over a two-week period in individuals with alcohol use disorder. The study found that expanding the temporal window using EFT reduced alcohol consumption. Together, these two studies provide support to employing interventions that expand the temporal window to change drug valuation and consumption. The construction of multi-component treatments that incorporate interventions expanding the temporal window may reduce drug consumption.

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INTRODUCTION

Testing the Reinforcer Pathology Theory: A New Insight into Novel Targets for Drug Addiction

"The dogmas of the quiet past are inadequate to the stormy present. The occasion is piled high with difficulty, and we must rise with the occasion. As our case is new, so we must think anew and act anew."

-Abraham Lincoln

In the united states, alcohol and drug addiction is one of the leading public health challenges (Nutt, Robbins, Stimson, Ince, & Jackson, 2006; on Drug Abuse, 2005) with over $600 billion dollars (Volkow, 2011) of annual cost and more than 20 million Americans meeting the diagnostic criteria for substance use disorders (SUDs) other than for tobacco (U.S. Department of Health and Human Services (HHS), 2016). Despite decades of effort developing evidence-based treatments, drug misuse remains one of the most problematic and enduring public health crises (Center for Behavioral Health Statistics and Quality, 2015; Sacks, Gonzales, Bouchery, Tomedi, & Brewer, 2015). Developing a new generation of theoretically-derived interventions responsive to substance-related problems constitutes an important clinical and scientific gap that if addressed may open innovative treatment opportunities.

Decades of research work in psychology, economics, neuroscience and information sciences (Bickel, Snider, & Mellis, 2019; Bickel et al., 2017a; Bickel, Wilson, Chen, Koffarnus, & Franck, 2016; Gupta & Merchant, 2017; Okamoto & Fukai, 2009; Snider, LaConte, & Bickel, 2016) has led to the development of a novel conceptual framework of addiction, Reinforcer Pathology. Reinforcer Pathology theory seeks to understand the mechanisms that determine the

excessive valuation of unhealthy reinforcers such as drugs. According to the Reinforcer Pathology theory, the temporal window over which reinforcers are integrated interacts systematically with reinforcers (e.g., drugs and prosocial activities) to determine their relative value. The theory suggests that individuals who integrate the value of reinforcers over a narrow temporal window (e.g., individuals with addiction; Snider et al., 2016) will overvalue reinforcers that are brief, immediate, intense, and reliable such as drugs while discounting both the delayed negative consequences associated with substance use as well as the prosocial reinforcers that are lower in intensity, variable in outcome, and accrue in value over time (such as social relationships; Bickel et al., 2017). In contrast, individuals with an extended temporal window (i.e, can imagine and consider outcomes further in the future) will place greater value on future rewards and therefore regard the negative consequences of harmful brief intense reinforcers (e.g., drugs) and the positive future rewards of prosocial activities leading to better decision making and less valuation of drugs. Hence, according to the Reinforcer Pathology theory, extending the temporal window would amplify the value of delayed reinforcers such as prosocial activities while limiting the value of immediate rewards.

The temporal window of integration can be measured with delay discounting, which refers to the process in which the present value of a reward declines as a function of the delay to its receipt. A growing body of evidence has identified delay discounting as a candidate behavioral marker of addiction, with excessive discounting being a trans-disease process contributing to addiction and other disease-related vulnerabilities (Bickel, Jarmolowicz, Mueller, Koffarnus, & Gatchalian, 2012; Bickel, Koffarnus, Moody, & Wilson, 2014). Previous studies indicated that relationships between discounting and addictive behaviors have both state- and trait-based components (Koffarnus, Jarmolowicz, Mueller, & Bickel, 2013; Story, Vlaev,

Seymour, Darzi, & Dolan, 2014). The Reinforcer Pathology theory suggests that altering the temporal window of valuation (manipulating rates of discounting) may alter the valuation of drug reinforcers.

One method to alter the temporal window is the novel framework of narrative theory (Bickel et al., 2017a), which seeks to harness humans' unique sensitivity to language and storytelling (Huth, de Heer, Griffiths, Theunissen, & Gallant, 2016; Nummenmaa et al., 2014) to both understand and change behavior. Within this framework, participants are asked to read and vividly imagine narratives describing different environmental conditions in order to examine the effects of those conditions on behavior. Within the context of delay discounting, episodic future thinking (EFT), a narrative manipulation in which participants vividly imagine possible future events expands the temporal window of integration (i.e., decreases rates of discounting; Dassen, Jansen, Nederkoorn, & Houben, 2016; Lin & Epstein, 2014; Snider et al., 2016; Stein et al., 2016). In contrast, narratives describing economic scarcity shortens the temporal window of integration (i.e., increases rates of discounting; Bickel et al., 2016; Sze, Y., Stein, J. S., Paluch, R., Bickel, W. K., & Epstein, L. H., 2017). Moreover, the effect of other narratives including economic abundance, mortality cues, episodic past thinking, and sexual regret expression on delay discounting has been investigated with different findings depending on the populations studied or measures used(Bickel et al., 2017b). However, to our knowledge, no previous studies have investigated the effect of altering the temporal window in both directions (extending and shortening in the same study) to assess its effect on drug valuation. In addition, no previous studies have tested the Reinforcer Pathology theory in real-world settings.

In the subsequent studies, we tested the Reinforcer Pathology theory first online among cigarette smokers and second in a real-world trial among individuals with AUD. In the first

study, two different mating narratives (long term and short term relationships) are used to experimentally expand and constrict the temporal window (measured using delay discounting) in order to assess the effect on cigarette valuation. In the second study, EFT narratives are remotely delivered to individuals with AUD to expand their temporal window and assess the effect on real-world alcohol consumption. Together, these studies test the Reinforcer Pathology theory to better define novel interventions that can be clinically employed to reduce drug use.

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MANUSCRIPT 1

Title

Narrative Theory III: Evolutionary Narratives Addressing Mating Motives Change Discounting and Tobacco Valuation

Abstract

Relationships between discounting and addictive behaviors have both state- and trait-based components. Evolutionarily driven motives may trigger risk-taking behaviors, and narratives might be used to alter the temporal window of reward valuation. The current investigation—in two separate studies—sought to understand the basic effects of narratives on smoking behavior by examining the effect of mating narratives on the discounting rates of cigarette smokers. Using data collected online, Study 1 (N= 132) assessed the within-individual effect of a mating narrative describing a long-term romantic relationship on rates of discounting after being randomly assigned to 1 of 2 narratives (romance or control) and Study 2 (N= 273) assessed the between-individual effect of 2 mating narratives (1 describing a long-term romantic relationship and 1 describing a short-term sexual encounter) on rates of discounting, craving, and cigarette valuation after being randomly assigned to 1 of 3 motivational narratives (romance, sex, or control). Reading the romance narrative decreased rates of discounting (i.e., increased preference for larger delayed rewards), compared to a control narrative (Studies 1 and 2). In contrast, reading the sexual narrative increased discounting (i.e., decreased preference for larger delayed rewards). Moreover, the romance narrative significantly decreased the craving of cigarettes while the sexual narrative increased cigarette valuation (Study 2). These findings suggest that mating narratives may be useful in manipulating the temporal window of reward valuation, relevant for altering demand and craving, and may show Potential as a component of future behavioral addiction interventions. Given the small effect sizes, replicating the study in future research will be beneficial.

Keywords: cigarette smoking; mating; narrative theory; evolutionarily driven motives; delay discounting

Introduction

Over the last few decades, the "narrative turn" in psychology and social science has had a vital role in the field of psychotherapy (e.g., Krippner, Bova, & Gray, 2007; McLeod, 1997; Meier, 2012; Speedy, 2008; White & Epston, 1990). Narrative theories have emerged from the premise that human beings are storytellers by nature (Gregg, 1991; Hermans, 1993; McAdams, 1988; McAdams, Josselson, & Lieblich, 2006). Research and interest in utilizing narratives to change behaviors–especially in addiction–has been gaining ground. Narratives have been applied in many forms to foster behavioral change. For example, within a novel framework of narrative theory (Bickel et al., 2017) that seeks to harness humans' unique sensitivity to language and storytelling (Huth, de Heer, Griffiths, Theunissen, & Gallant, 2016; Nummenmaa et al., 2014) to study human behaviors, research participants are asked to read and vividly imagine narratives describing different environmental conditions in order to examine the effects of those conditions on behavior. For instance, Episodic Future Thinking (EFT), a narrative manipulation in which participants self-generate and vividly imagine possible future events, expands one's temporal window of reward valuation (i.e., increases valuation of future rewards while decreasing valuation of immediate rewards, such as drugs) and decreases self-administration of reinforcers, such as food (Daniel et al. 2013) and cigarettes (e.g., Stein et al. 2016). In addition, EFT decreases behavioral economic demand (i.e., consumption as a function of price; a measure of reward valuation) for addictive substances, such as cigarettes (Stein et al. 2018), alcohol (Bulley and Gullo 2017; Snider et al. 2016), and food (Sze et al. 2017) in smokers, alcohol-dependent individuals, and overweight/obese individuals, respectively. In contrast, reading narratives that describe economic scarcity shortens the temporal window (i.e., increases valuation of immediate rewards; Bickel, Wilson, Chen, Koffarnus, & Franck, 2016; Sze, Stein,

Paluch, Bickel, & Epstein, 2017) and increases intensity of behavioral economic demand (i.e., consumption when a commodity is free) for fast food among overweight/obese individuals (Sze et al. 2017).

As previously described by Bickel et al. (2017), the temporal window of reward valuation and drug valuation are two behavioral economic constructs associated with problematic substance use and other problem health behaviors. The temporal window can be measured using delay discounting, which refers to the process in which the present value of a reward declines as a function of the delay to its receipt. A growing body of evidence has identified delay discounting as a candidate behavioral marker of addiction, with excessive discounting being a trans-disease process contributing to addiction (Bickel, Jarmolowicz, Mueller, Koffarnus, & Gatchalian, 2012; Bickel, Koffarnus, Moody, & Wilson, 2014). This finding has been replicated many times among cigarette smokers (Baker, Johnson, & Bickel, 2003; Bickel, Odum, and Madden 1999; Krishnan-Sarin et al. 2007; Odum et al. 2002; Sheffer et al. 2014; ; Sheffer et al. 2012; Yoon et al. 2007). The relationships between discounting and addictive behaviors have both state- and trait-based components (Koffarnus, Jarmolowicz, Mueller, & Bickel, 2013; Story, Vlaev, Seymour, Darzi, & Dolan, 2014).

Drug valuation can be measured using behavioral economic demand, which refers to the quantitative association between the price of a commodity and the amount purchased (Acker and MacKillop 2013; Hursh 1980; MacKillop et al. 2012). Previous research has indicated a negative association between cigarette prices and consumption (Buczkowski et al. 2014; Douglas 1998; Forster and Jones 2001; Ross et al. 2011). Furthermore, greater demand for cigarettes is associated with a higher number of daily cigarettes consumed (Few et al. 2012; MacKillop et al. 2008; Murphy et al. 2011) and less sensitivity to changes in cigarette prices (MacKillop et al.

2012). Hence, identifying interventions, including those informed by narrative theory, that shift smoker's preference from immediate to long-term rewards by expanding the temporal window and/or decreasing demand for cigarettes may facilitate healthy behavior change among smokers and amend behaviors related to smoking.

Recently, evolutionarily-driven motives (e.g., self-protection, status, mate acquisition, mate retention, and kin care) have been suggested to trigger risk-taking behaviors (Kenrick & Vladas, 2013). Priming sexual motives activates the human reward circuitry that processes monetary and drug rewards (Stark et al., 2005) and levels of sexual arousal are *positively* associated with risk taking (Baker & Maner, 2009; Skakoon-Sparling & Cramer, 2014). For example, experiencing high levels of sexual arousal is associated with greater willingness to make risky plays in a Blackjack game (Baker & Maner, 2008; Skakoon-Sparling & Cramer, 2014; Skakoon-Sparling, Cramer, & Shuper, 2016), and with greater willingness to procure sex by engaging in a wide range of morally questionable behaviors and risky sexual activities (e.g. unprotected sex with a new partner, having sex with an underage or significantly older partner, and engaging in sex acts with multiple partners, etc.; Ariely & Loewenstein, 2006; Skakoon-Sparling, Cramer, & Shuper, 2016). Exposure to sexual cues shortens the temporal window and therefore, increases preference for immediately available rewards over larger but delayed ones (Ariely & Loewenstein, 2006; Van den Bergh, Dewitte, & Warlop, 2007; Wilson & Daly, 2004). Previous studies have demonstrated a significant increase in temporal discounting among men who were exposed to stimuli that increase a sexual mindset (e.g., touching lingerie or viewing pictures of attractive women; Wilson and Daly 2004; Van den Bergh et al. 2007). In addition, exposure to sexual cues increases cigarette consumption. For instance, male smokers with an intention to quit or reduce smoking were less likely to abstain from smoking and smoked more

cigarettes when exposed to photographs of attractive females compared to less attractive ones (Chiou et al. 2015).

Priming of mating motives can influence individuals' real-life beliefs and attitudes (Diekman, Gardner, & McDonald, 2000; Griskevicius, Goldstein, Mortensen, Cialdini, & Kenrick, 2006; Griskevicius et al., 2007; Iredale, Van Vugt, & Dunbar, 2008). Evolutionary narratives (i.e., narratives addressing evolutionary needs and fundamental motives such as self-protection, mate acquisition, and mate retention), including those described in romance novels may have a significant effect on readers' sexual attitudes and behaviors (Anderton, 2009; Cabrera & Ménard, 2012; Diekman, Gardner, & McDonald, 2000; Quilliam, 2011). Higher frequency of reading romantic fiction (usually including sexual scripts) is associated with negative attitudes towards condoms and reduced future intent to use them (Diekman et al., 2000). However, including safe sex components in romance novels increased positive attitudes toward condoms and marginally increased intention to use them in the future, even when individual characteristics such as previous exposure to romance novel (might reflect high arousability or sensation seeking) were experimentally controlled (Diekman et al., 2000). Romance stories, even if clearly fictional, can be easily incorporated into memory (Cabrera & Ménard, 2012; Diekman et al., 2000). This incorporation is enhanced by both the stimulation and vividness of the story. The association between priming mating motives and decision-making raises an important question of whether altering the temporal content of relationship narratives (long-term romance vs short-term sexual relationships) plays a role in changing discounting rates and drug valuation, and, therefore, shaping the attitudes and behavior of readers. However, it is critical to keep in mind that clinical use of narratives will first require more basic research to identify narratives that will interact with processes that may undergird aspects of drug use.

The current investigation

The temporal window of reward valuation and cigarette demand are associated with smoking behaviors (Baker, Johnson, & Bickel, 2003; Bickel, Odum, & Madden, 1999). Priming mating motives may alter the temporal discounting (Wilson and Daly 2004; Van den Bergh et al. 2007) and cigarette consumption (Chiou et al. 2015) and may therefore change smoking behaviors. The current investigation, in two separate studies, sought to understand the basic effects of narratives on smoking behavior by examining the effect of two mating narratives (long term romance vs short term sexual relationships) on the discounting rates and cigarette valuation among cigarette smokers. Study 1 used an adjusting-delay discounting task, a brief but accurate method of obtaining discount rate (Koffarnus and Bickel 2014) to assess the within-individual effect of mating narratives describing long-term romance relationship (occurring over a long temporal window) on rates of discounting. Study 2 sought to validate and extend the results of Study 1 by examining the in between-individual effects of both a long-term romantic relationship narrative and a short-term sexual encounter narrative on cigarette valuation and on delay discounting rates using an adjusting-amount discounting task, a more standard and lengthier method of obtaining discount rate (Du, Green, and Myerson 2002; Mazur 1987). As cognitive control is important for maintaining long-term relationships (Pronk, Karremans, & Wigboldus, 2011; Ritter, Karremans, & van Schie, 2010) and being in a stable, long-term relationship is *negatively* associated with risk behaviors (Amato & Kane, 2011; Fleming, White, & Catalano, 2010; Fleming, White, Oesterle, Haggerty, & Catalano, 2010), we hypothesized that, in cigarette smokers, reading and vividly imagining the long-term romantic relationship narrative would be associated with lower rates of discounting and less valuation of cigarettes compared to control,

while reading and vividly imagining the short term sexual narrative would be associated with higher rates of discounting and higher valuation of cigarettes compared to controls.

Study 1

Methodology

Participants. The study was carried out using data collected online from mTurk, a crowdsourcing service in which employers post Human Intelligence Tasks (HITs) that may be completed online in exchange for a previously determined monetary payment. Data was collected in May 2017. Eligibility was assessed using a brief screening questionnaire. To be eligible to accept the posted HIT, participants were required to (1) be located in the United States; (2) have a HIT approval rate greater than 95%; (3) be 18 years or older; and (4) smoke at least 10 cigarettes per day. Participants were excluded from the analysis if they failed the attention check question (Which of the following would you prefer? $1000 in 1 day or $0.00 now). A total of 132 participants completed the online questionnaire, of which 41 participants were females. All participants passed the attention check question and were included in the analysis.

Design and procedure. Participation in the study was voluntary. Completion of the survey was considered implied consent to participate in the study. The study was approved by the Institutional Review Board (IRB) at Virginia Polytechnic Institute and State University (Protocol number 16-983; "The effect of evolutionary driven narratives on discounting rates"). Participants received $2.50 compensation upon completion of the study, which required approximately 20-30 minutes to complete. Participants were randomly assigned to one of two narratives (long-term romantic relationship narrative or control) in a within-subjects

experimental design. The narratives used in this study were primed via guided visualization exercises that were modified from pre-tested and previously-used narratives that have been shown to stimulate mating motives (significantly more romantic arousal and a stronger desire to attract a romantic partner compared to the control condition) for both men and women (Griskevicius et al., 2006, 2009, 2007; Li, Kenrick, Griskevicius, & Neuberg, 2012; Sundie et al., 2011). After completing a brief demographics questionnaire and baseline adjusting-amount discounting task (Du et al., 2002), participants were asked to read the assigned narrative and complete an adjusting-delay discounting task for the second time (post intervention).

Motivations manipulation. Each guided visualization narrative consisted of about 800 words (see Appendix 2). In the romance condition, participants were asked to imagine meeting an attractive person at the beach. As the scenario unfolds, participants imagine having an absolutely wonderful time at the beach chatting and walking together while daydreaming of a long-term relationship full of great moments, including cuddling on the couch, waking up to good morning kisses, having arguments but making up after, cooking their favorite food, smiling for no reason, and never leaving each other's side. The day ends with a passionate kiss and looking forward to an exciting long-term relationship. To limit the effect of reading a story or paying attention to details on the study outcome measures, participants in the control group read a scenario of comparable length that did not involve any romantic or sexual content. Instead, participants imagined themselves working at home. While working, they decide to go buy some groceries but can't find their car keys. They spend some time looking for the lost keys and when they find them they change their mind and decide to stay at home to finish their work (Wang & Griskevicius, 2014).

Study measures. We collected demographic data including age, monthly income,

gender, race, ethnicity, the number of cigarettes smoked per day, and education level.

Fagerström Test for Cigarette Dependence (FTCD). A valid and reliable measure to evaluate cigarette dependence (Fagerström, 2012). FTCD consists of six items that assess the quantity of cigarette consumption, the urge to use cigarettes, and dependence. Scores range from 0 to 10. The higher the total Fagerström score, the greater is the participant's dependence on cigarettes (Fagerström, 2012; Fagerström et al., 1996; Ferguson et al., 2003). In the current study Cronbach's alpha (*a*) for the 6 FTCD items was .67.

Patient Health Questionnaire (PHQ-9). A self-administered, brief version of the full Patient Health Questionnaire (PHQ) (Kroenke, Spitzer, & Williams, 2001). The PHQ-9 has been validated for use in primary care as a diagnostic instrument and to assess severity of depression (Spitzer, Kroenke, & Williams, 1999; Spitzer, Williams, Kroenke, Hornyak, & McMurray, 2000). The PHQ-9 score can range from 0 to 27, with higher scores indicating higher levels of depression. In the current study, PHQ-9 was found to be reliable (9 items; *a*= .85).

The adjusting-delay task. Delay discounting was measured using the adjusting delay task (Koffarnus & Bickel, 2014). The adjusting-delay task is a five-trial task that determines the delay at which the subjective value of the larger reward is decreased by half. Participants are asked on the first trial to choose between receiving $1000 in 3 weeks or receiving half of that amount ($500) now. On the next trial, the same question is presented but with a different time delay, depending on the participant's prior choice. That is, the greater delay is presented on the subsequent trial if the participant chose "now" on the previous trial, and the lesser delay is presented on the subsequent trial if the participant chose the "later" reward on the previous trial.

Positive and Negative Affect Schedule (PANAS). PANAS has demonstrated high internal consistency and test-retest reliability (Watson, Clark, & Tellegen, 1988) in measuring aspects of

positive affect (active, alert, attentive, determined, enthusiastic, excited, inspired, interested, proud, strong; a= .88 in the current study) and negative affect (afraid, ashamed, distressed, guilty, hostile, irritable, jittery, nervous, scared, upset; Watson, Clark, & Tellegen, 1988; a= .96 in the current study). Each item was rated on a 5-point scale (*not at all* to *extremely*).

Statistical analyses. In the adjusting-delay task, the Effective Delay 50 (ED_{50}) represents the delay expected to reduce the value of the larger reward by 50% or the indifference point (expressed in days). The inverse of ED_{50} ($1/ED_{50}$) provides an estimate of k (Koffarnus & Bickel, 2014; Yoon & Higgins, 2008). The observed k values were non-normally distributed (positive skew), so we used the natural log transformation of k in analyses. Descriptive statistics, chi square and t-test analysis were used to determine means and the frequencies of sample characteristics, ED_{50}, PHQ-9, FTCD, and PANAS scores in the two groups. As gender and marital status might alter the effect of mating narratives on discounting, a repeated measure analysis of covariance (ANCOVA) was conducted to determine a statistically significant difference between narrative groups on discounting rates controlling for gender and marital status. SPSS was used to perform all of the statistical analyses ($\boldsymbol{\alpha}$= 0.05)

Results

The distribution of the socio-demographic characteristics, PHQ-9, FTCD, and PANAS scores for cigarette smokers who participated in Study 1 is shown in Table 1.1. The repeated measure ANCOVA results indicated a significant effect of narrative on discounting rates [$F(1, 126) = 9.059$, $p<.003$, $\omega^2_p=0.055$] after controlling for gender and marital status with a significant reduction in rates of discounting for the romance group from pre- (M=-4.13, SD=3.10, M_{ED50}=1.54 years) to post-narrative (M=-4.94, SD=2.48; $t(66)=3.12$, p=.005, ω^2_p=0.049, M_{ED50}=2.42 years). For the control group, no significant change in rates of discounting was

observed between pre- (M=-4.15, SD=3.32, M_{ED50}=1.97 years) and post-narrative assessments (M=-3.67, SD=3.29; $t(64)$=-1.20, p=.131, ω^2_p = 0.040, M_{ED50}=1.54 years) (Figure 1.1).

Brief Discussion

Our prediction was that reading a long-term relationship narrative would expand cigarette smokers' temporal window. Supporting this prediction, cigarette smokers in the romance condition had significantly lower rates of discounting compared to their baseline rates (see Figure 1.1). Importantly, the control narrative did not significantly change smokers' rates of discounting compared to before reading the narrative (Figure 1.1). Although the main findings are in agreement with our predictions, the current study had two key limitations. First, the study did not investigate the effect of shortening the temporal window (e.g., including a short-term relationship narrative) on the temporal window. Second, the study did not address the effect of mating (long-term or short-term relationship) narratives on cigarette valuation and demand. Cigarette demand (valuation) has demonstrated utility in research assessing drug abuse liability, craving, and withdrawal (Hursh and Silberberg 2008; MacKillop et al. 2012) and is widely used to assess smoking motivation (Vuchinich and Heather 2003). A commonly used and validated measure of cigarette demand is the cigarette purchase task (CPT). In the CPT, individuals indicate the number of cigarettes they would buy at escalating prices (MacKillop et al. 2008; Stein et al. 2018; Wilson et al. 2016). Purchase tasks allow assessment of various demand indices including intensity (i.e., consumption when cost is zero), elasticity (i.e., the change of consumption with increasing price), *P*max (i.e., the price at which consumption changes from being inelastic to elastic), *O*max (i.e., maximum expenditure allocated for a drug), and breakpoint (i.e., price at which consumption is zero). To increase the efficiency and utility of behavioral cigarette demand in novel research and clinical settings, a brief single-item behavioral

economic assessment of demand among cigarette smokers was recently validated (Athamneh et al. 2019). The brief measure assesses the maximum price that a smoker is willing to pay for one cigarette received right now and is significantly correlated with CPT-derived measures of elasticity, breakpoint, *O*max and *P*max. In addition, the brief behavioral demand measure is associated with metrics of tobacco dependence and craving (Athamneh et al. 2019).

Thus, before discussing the findings in Study 1, we aimed to replicate them in Study 2, using a different measure of discounting and adding the brief breakpoint measure of cigarette valuation. Moreover, we added a short-term sexual encounter narrative to assess the effect of shortening the temporal window on rates of discounting and the included measures. In addition, while Study 1 assessed the within-individual effect of narratives on discounting rates, Study 2 assessed the between-individual effect.

Study 2

Methodology

Participants. Similar to Study 1, this study was carried out using data collected online from mTurk and eligibility was assessed using a brief screening questionnaire. Data was collected in August 2017. This study had the same inclusion criteria as Study 1 and participants were excluded from the analysis if they failed the attention check question in which participants were asked to choose between receiving $0 now or $1000 in one day. Participants received $2.50 compensation upon completion of the study, which required approximately 20-30 minutes to complete. A total of 316 participants completed the study. Two subjects were excluded due to failing the attention check test (choosing $0 now instead of $1000 in one day). In addition, 41 subjects (n=14 romance, 13 sex, and 14 control participants) were excluded because their discounting data were identified as nonsystematic according to Johnson and Bickel's (2008)

standardized criteria. Thus, 273 subjects (90 females) were included in the final analysis.

Design and procedure. Participation in the study was voluntary. Completion of the survey was considered implied consent to participate in the study. The study was approved by the Institutional Review Board (IRB) at Virginia Polytechnic Institute and State University (Protocol number 16-983; "The effect of evolutionary driven narratives on discounting rates"). Participants were randomly assigned to one of three narrative conditions (romance, sex, or control) in a between-subjects experimental design. The narratives used in this study were primed via guided visualization exercises that were modified from pre-tested and previously-used narratives (Griskevicius et al., 2006, 2009, 2007; Sundie et al., 2011). After completing a brief demographics questionnaire and reading the scenario, participants completed an adjusting-amount discounting task (Du et al., 2002) and a battery of assessments including measures of cigarette dependence, craving, and valuation that were presented in a random order.

Motivations manipulation. Similar to Study 1, each guided visualization narrative consisted of about 800 words (see the supplementary materials). We used the same long-term romantic and control narratives used in Study 1. In the sexual narrative, participants were asked to imagine meeting a physically attractive person at the beach. As the scenario unfolds, participants imagine being touched and kissed by that person and having a great time with them. Moreover, the participant gets invited to that person's hotel room and the story ends with a passionate kiss and feeling excited about experiencing one of the most memorable nights of his/her entire life.

Study Measures. We collected demographic data including age, monthly income, gender, race, ethnicity, the number of cigarettes per day, and education level (Table 1.2). Similar to Study 1, the FTCD, PHQ-9, and PANAS measures were collected as well.

Narrative manipulation check. As a manipulation check, we asked participants in the romance and sex groups to imagine the narrative happening right now and rate (from 1-10) their level of sexual arousal, desire to have a sexual relationship, and the desire to have others be attracted to them physically or sexually. One-way ANOVA analyses were used to compare scores for each of the manipulation check items among the motivational narrative groups. As expected, participants in the sex condition reported a significantly greater level of sexual arousal (M = 7.08, SD= 2.77, p= .003), greater desire to have a sexual encounter (M = 7.91, SD= 2.34, p<.001), and greater desire to have others be attracted to them physically or sexually (M = 7.95, SD = 2.43, p=.005), compared to participants in the romance condition (M = 5.75 SD= 3.024, M = 6.43 SD= 3.039, M = 6.87 SD= 2.64, respectively).

The adjusting-amount task. Delay discounting was measured using the adjusting-amount task. The adjusting-amount task determines the amount of immediate money that is approximately equal to $1,000 that is delayed by seven discrete durations of time (i.e., 1 day, 1 week, 1 month, 6 months, 1 year, 5 years, and 25 years). At the first trial, the participant chooses between a delayed $1,000 and $500 available immediately. Depending on the choice made by the participant, the amount of the smaller, immediate reward is titrated up (if the delayed reward was chosen) or down (if the immediate reward was chosen) until an indifference point is reached. Across six trials within each delay, the immediate amount is adjusted by an amount half that of the previous adjustment (see Du et al., 2002). The indifference point reveals the extent to which the delayed $1000 has been discounted (e.g., an indifference point of $750 indicates the delayed $1000 has been discounted by 25%). Discounting curves were fit using the following hyperbolic equation,

$$V=A/(1+kD)$$

in which V refers to the discounted value of a delayed reward; A represents the amount of the delayed reward; D equals the delay of the award; and k is a derived parameter that represents the delay-discounting rate (Mazur, 1987). A higher k value means a steeper discounting curve (higher discounting rates) and greater impulsivity, while a lower k value represents a shallower discounting curve (lower discounting rates) and less impulsivity.

The Questionnaire of Smoking Urges (QSU-brief). A shortened version of the original Questionnaire of Smoking Urges (QSU; Tiffany & Drobes, 1991). Using ten 'agree-disagree' Likert items, the QSU-brief assesses the craving to smoke. The 10-item QSU consists of two factors (5 items each). Factor 1 represents a strong desire to smoke, with smoking perceived as rewarding. Factor 2 reflects an anticipation of relief from negative affect (Cox, Tiffany, & Christen, 2001). The scores of both subscales were examined in this study.

Cigarette valuation. Cigarette valuation was assessed using two versions of a brief breakpoint measure of demand. Both breakpoint versions were previously tested and validated against the CPT among smokers and are significantly correlated with CPT-derived measures of elasticity, breakpoint, O_{max} and P_{max} (Athamneh, Stein, Amlung, & Bickel, 2018). To measure the valuation of cigarettes when paid out of pocket, in the first breakpoint version, participants were asked to answer the following question: "What is the maximum price you would be willing to pay for 1 cigarette received NOW?" We asked the participant to assume that he/she has no access to any cigarettes or nicotine products other than those offered in that question.

To limit the effect of income on the maximum price someone would pay for a cigarette, in the second breakpoint version, participants imagined receiving a $100 gift card for free (Athamneh et al., 2018). Participants were asked to assume this gift card could be used only for buying cigarettes, does not expire, and neither the gift card nor the cigarettes purchased could be sold,

given away, or shared. Then we asked: "Using only the $100 gift card, what is the maximum price you would be willing to pay for 1 cigarette received NOW?" Again, participants were asked to assume that they have no access to any cigarettes or nicotine products other than those offered in the question.

Statistical Analyses. Chi-square and t-test analyses were used to compare means and frequencies of sample characteristics for participants included in the study (n=273) and those who were excluded for providing non-systematic discounting or failing the attention check (n=43). For participants included in the study, descriptive statistics, chi-square, and one-way ANOVA analyses were used to compare means and frequencies of sample characteristics, PHQ-9, FTCD, and PANAS scores among the three motivational narrative groups. In addition, because PANAS scores were significantly different between groups (Table 1.2), gender was at the borderline level of statistical significance (p=.054), and marital status might impact relationships, a multivariate analysis of covariance (MANCOVA) was conducted to determine a statistically significant difference between narrative groups on discounting rates, cigarette valuation, and craving scores, controlling for gender, marital status, and PANAS scores (Table 1.3). Planned post hoc comparisons between the two motivational groups and the control group were conducted using the Dunnett's test for the outcome measures included in the study (Table 1.4). All the statistical analyses were conducted using SPSS at a significance level of 0.05.

Results

No significant differences in gender (p=.480), marital status (p=.462), education level (p=.067), income (p=.478), age (p=.172), or FCND score (p=.175) were found between participants included in the study (n=273) and those who were excluded (n=43) for providing non-systematic discounting or failing the attention check. However, those excluded from the study had significantly higher PHQ-9

scores (M = 11.88, SD= 8.20) compared to the scores obtained from participants included in the study (M= 7.27, SD= 6.576, p< .001). The distribution of the socio-demographic characteristics, PHQ-9, FTCD, and PANAS scores for cigarette smokers who participated in the study is shown in table 1.2. Discounting data were well described by the hyperbolic equation, with median R-squared values of 0.908, 0.902, and 0.934 across participants in the romance, sex and control groups, respectively. The MANCOVA analyses indicated a significant main effect of narrative type on discounting rates (ω^2=0.065), cigarette valuation (out of pocket) (ω^2=0.059), cigarette valuation ($100 gift card) ($\omega^2$=0.193), QSU factor 1 ($\omega^2$=0.028) and QSU factor 2 (ω^2=0.051) scores among the three motivational narrative groups (Table 1.3). When compared to controls, those who read the romantic narrative had significantly lower rates of discounting (p=0.044) while those who read the sexual narrative had higher discounting rates (p=0.049) (Figure 1.2). In addition, the romance group reported significantly less craving (factor 1 (p=.033), and factor 2 (p=.0025)) while the sex group reported higher cigarette valuation (out of pocket (p<.001) and using the $100 gift card ($p$<.001); Figure 1.3). Post-hoc results for the mean and standard deviation for those measures among the three motivational groups and the significant p values when mating groups were compared to controls are shown in table 1.4.

General Discussion

In this investigation, using two separate studies, we examined the effects of long-term romantic and short-term sexual narratives on rates of discounting, cigarette craving, and valuation. Analyses showed that participants were more inclined to choose the delayed but larger rewards after reading the romance narrative compared to control. However, reading the sexual narrative increased their choice preferences for the immediate but smaller rewards. The effect size, as measured by omega squared ω^2 (Olejnik and Algina 2003), was medium. Moreover,

reading the romance narrative significantly decreased craving for cigarettes (with a small to medium effect size) while reading the sexual narrative increased cigarette valuation (with a medium to large effect size). Below we discuss these findings from an evolutionary perspective, and in general.

An evolutionary perspective suggests that to survive, thrive, and replicate (Ackerman and Kenrick 2008; Griskevicius and Kenrick 2013; Kenrick et al. 2003; Kenrick et al. 2010), all living organisms evolved to behave in ways that offer them an evolutionary advantage. To achieve evolutionary success, humans have to surmount a number of prominent evolutionary challenges. These fundamental challenges include self-protection, affiliation, status, mate acquisition, mate retention, and caring for family (Ackerman & Kenrick, 2008; Griskevicius & Kenrick, 2013; Kenrick, Li, & Butner, 2003; Kenrick, Neuberg, Griskevicius, Becker, & Schaller, 2010). Humans employ different psychological systems to cope with different evolutionary challenges (e.g., Barrett, 2012; Bugental, 2000; Fiske, 1992; Lieberman, Tooby, & Cosmides, 2007; Maner, Miller, Moss, Leo, & Ashby Plant, 2012; Saad, 2007; Tybur, Lieberman, & Griskevicius, 2009) and activation of a specific fundamental motive shapes preferences and guides decision-making processes (Griskevicius & Kenrick, 2013). The mate acquisition system (e.g., sexual motives) alters decision making, leading to an increase in risk-seeking (Baker & Maner, 2009; Baker & Maner, 2008; Griskevicius & Kenrick, 2013; Knutson, Wimmer, Kuhnen, & Winkielman, 2008) and impulsivity (Ariely & Loewenstein, 2006; Skakoon-Sparling, Cramer, & Shuper, 2016; Van den Bergh et al., 2007; Wilson & Daly, 2004). For example, men exposed to sexy cues (touching a woman's lingerie) prefer small but immediate rewards over larger but delayed ones (Van den Bergh et al., 2007). However, the challenge of maintaining a long-term relationship and keeping a mate is very different from that of finding a short-term mate (Griskevicius & Kenrick, 2013). The mate retention motive

stimulates people to behave in ways that ensure the maintenance of their long-term romantic relationship. For instance, individuals motivated to retain their mate tend to devalue other attractive alternative partners (Lydon, Fitzsimons, & Naidoo, 2003) and may refrain from performing behaviors that would negatively affect their relationship or increase the likelihood of losing their mate (Buss and Shackelford 1997; Buss and Shackelford 2008), including drug use (Fleming et al. 2010; Newcomb 1994).

Another potential explanation for the current findings of higher impulsivity and valuation for cigarettes among the sexual narrative group and lower impulsivity and craving among the romantic narrative group is related to the Competing Neurobehavioral Decision Systems (CNDS) theory. Prior studies suggest that relationships with high infatuation -an intense passion for someone or something (e.g., sexual motives)- may stimulate reward-related responses (Aron et al., 2005) and reduce cognitive control (Skakoon-Sparling and Cramer 2016; van Steenbergen et al. 2013; Wolfs et al. 2019) and sexual self-restraint (Skakoon-Sparling and Cramer 2016; Turner et al. 2019). Increased cognitive control, however, is vital for maintaining long-term relationships (Pronk, Karremans, & Wigboldus, 2011; Ritter, Karremans, & van Schie, 2010). These study findings support the possibility that intense feelings (triggered by the sexual narrative) toward a sexually attractive person or a familiar partner may create a particularly vulnerable state for risk taking (Sparling and Cramer 2015), as we showed that sexual motives are positively associated with higher impulsivity and cigarette valuation, while a romantic and long-term relationship narrative is positively associated with higher impulse control and less craving. The current investigation findings are consistent with previous research using narratives to modulate delay discounting and drug valuation. Expanding the temporal window using a long-term romantic narrative increased valuation of future rewards and decreased craving of

cigarettes. This finding complements findings from studies using other narratives (e.g., EFT) to expand the temporal window and increase valuation of future rewards while decreasing valuation of immediate rewards (e.g., drugs; Dassen et al. 2016; Stein et al. 2016; Snider et al. 2016; Lin and Epstein 2014). In addition, shortening the temporal window using a short-term sexual narrative has effects that are similar to those obtained by other narratives (e.g., economic scarcity) that aim to shorten the temporal window and increase valuation of immediate rewards (e.g., drugs; Bickel et al. 2016; Sze et al. 2017). The current findings suggest that delay discounting may be a valuable target for interventional therapies that aim to alter cigarette valuation and therefore consumption. More research will be needed to assess these effects as well as how long they may last beyond the moments following reading the narrative.

In addition, the significantly higher discounting and cigarette valuation among the sex group could be related to the increased arousal (caused by the sexual narrative) that might cause an acute state of sexual deprivation. Acute deprivation of reinforcers (e.g., drugs) has been demonstrated to alter discounting of money and that reinforcer. For example, nicotine deprivation and urge to smoke affect time perception (Sayette et al. 2005) and increase the number of cigarette puffs compared to after ad lib smoking (Madden and Bickel 1999). Short-term nicotine deprivation increases the degree of discounting of cigarettes (Mitchell 2004) as well as the degree of discounting of monetary rewards (Field et al. 2006; Yi and Landes 2012). Similarly, during craving, heroin addicts value Buprenorphine more compared to during satiation (Badger et al. 2007). In addition, individuals with opioid dependence have significantly higher rates of discounting of both delayed monetary and heroin rewards when experiencing opioid deprivation compared to satiation (Giordano et al. 2002). In the current investigation, participants in the sex condition reported a significantly higher level of sexual arousal, greater

desire to have a sexual encounter, and greater desire to have others be attracted to them physically or sexually compared to participants in the romance condition. Hence, the possible acute or brief sexual deprivation caused by the sexual narrative could be affecting rates of discounting among the sex group. However, as the current study did not assess actual sexual status (i.e., current deprivation or satiation) and did not assess the effect of reading the mating narratives on sexual discounting or sex demand compared to controls, future studies assessing these measures are warranted to reach firmer conclusions.

Mating motives can be triggered by internal cues (e.g., hormonal) or external cues (Kenrick, Griskevicius, Neuberg, & Schaller, 2010). Many external cues could elicit acquisition motives (e.g., sexual motives) including the presence of a real or an imagined sexually desirable person; being exposed to an image involving a desirable person (e.g., sexy ads, movies, or television shows); imagining a desirable encounter with that person; or reading a sexual script. On the other hand, mate retention motives can be activated by cues that celebrate a long-term relationship, such as thinking about an upcoming anniversary; the presence of a real or an imagined romantic partner with whom one imagines mutual future plans; growing old together, making a family; or the motive can be triggered by reading a long-term romantic script. As those different means of triggering mating motives could be equally effective in eliciting the appropriate motive for some individuals, triggering mating motives to guide decision making using written narratives could be especially important for individuals who have impaired prospective thinking (i.e., the incapacity to think prospectively about future events or outcomes), such as those with drug dependence, patients with autism, schizophrenia, depression, and other impulse-control problems (Bechara, Noel, & Crone, 2006; D'Argembeau, Raffard, & Van der Linden, 2008; Griffiths et al., 2012; Lind & Bowler, 2010; MacLeod et al., 2005; O'Connor,

Connery, & Cheyne, 2000; Wallace, 1956). Descriptive and evocative narratives could paint pictures and set the scene, which allows participants to experience the story from a specific and personal point of view and communicate how each moment feels, by delivering sight, sound, smell, taste and touch. This investigation findings demonstrated that modifying the content of mating narratives to manipulate discounting may show potential as a component of future behavioral addiction interventions. Future research is poised to compare different means of triggering motives among individuals with impaired prospective thinking and to investigate the effects of other fundamental motives (e.g., risk protection and kin care) on preferences, choices, and decision making.

Romantic fiction (usually including sexual scripts) has a wide audience and remains the top-selling sector of the book market, accounting for about $1.5 billion in book sales in the US alone in 2011 (Costanza, 2012). Given the current findings of significantly higher demand for cigarettes among cigarette smokers after reading sexual narratives, and given the previous research suggesting significant associations between drug demand and drug abuse liability, craving, withdrawal, and treatment success in preclinical (for a review, see Hursh and Silberberg 2008) and clinical research (MacKillop et al. 2012), future research targeted toward investigating the associations between exposure to romantic novels (and their content) and drug use and addiction is warranted.

Although the current investigation provides important new insights into the effects of mating motivations on altering discounting and drug valuation, our studies contain a number of limitations. One key limitation is not including a socio-sexuality measure and/or impression management measure. Converging evidence suggests that differences in socio-sexuality (i.e., willingness to engage in sexual relationships without signs of emotional relation or commitment)

are associated with differences in romantic partner preference (Balzarini et al. 2018; Brown, Sacco, and Medlin 2019; Gangestad and Simpson 1989; Simpson and Gangestad 1991a; Simpson and Gangestad 1991b). Thus, differences in socio-sexuality among the study participants might have had an effect on interest in and/or engagement with the assigned mating narratives. For instance, the effect of presenting the sexual narrative to unrestricted individuals (willing to engage in sexual relationships in the absence of emotional relation or commitment) who prefer more physically and sexually attractive romantic partners (Simpson and Gangestad 1992) may be different compared to presenting it to restricted individuals (do not engage in sexual relationships in the absence of emotional bonding or commitment) who typically prefer responsible and loyal romantic partners (Simpson and Gangestad 1992). Moreover, previous studies have indicated that impression-management and self-presentation motivations are positively associated with risk taking (e.g., tanning, alcohol, tobacco, and drug use; Hill and Durante 2011; Leary, Tchividijian, and Kraxberger 1994). Therefore, the level of impression-management activated by each narrative motive (sexual vs romantic) might differ and as a result, might affect rates of discounting differently. Future studies assessing the effect of mating motives on discounting should include measures of socio-sexuality and impression management.

In this investigation, participants were mostly males (61.7%, 77.6%, and 63.1% in the romance, sex, and control groups, respectively), with a high proportion of Caucasians (77.4% 72.6%, and 63.2% in the romance, sex, and control groups, respectively). Generalizing the results to broader populations should be done with those characteristics in mind and future research with broader populations may be necessary. Furthermore, we did not investigate the effect of gender on the relationship between mating motives and rates of discounting. As the effects of mating narratives might differ in males compared to females, future research that

includes assessing the effect on each gender is necessary to better understand the association between mating narratives and delay discounting rates.

Additionally, narratives used in this investigation have limited ecological validity and may not contain all of the stimuli and emotions that would be included in a real-life situation. Future studies designed to assess the ecological validity of those narratives and how closely they imitate real life situations may be needed. Further, while we predict that the long-term romantic narrative would elicit a mating retention motive (given its content), we did not assess if mate retention motives were actually activated and to what degree. Furthermore, we relied on participants' self-reported data about smoking status, which may have some potential sources of bias such as selective memory and social desirability bias. However, prior studies have validated self-report smoking status (Rebagliato, 2002; Wong, Shields, Leatherdale, Malaison, & Hammond, 2012). The current findings do not provide insight into the basis of the observed relations (for instance, in terms of neuropharmacologic or cognitive control processes). Hence, future research designed to tease these processes apart would be beneficial. Moreover, collecting data using mTurk limited our sample to online data only. However, previous studies have validated online data collection by reporting results similar to the laboratory-based data collection (Athamneh, Stein, & Bickel, 2017; Birnbaum, 2000; Buhrmester, Kwang, & Gosling, 2011; Paolacci, Chandler, & Ipeirotis, 2010; Suri & Watts, 2011). In addition, many discounting-related phenomena observed in traditional laboratory studies were replicated on mTurk studies, including cross-sectional differences in delay discounting related to cigarette smoking and alcohol use disorder (Athamneh et al., 2017; Jarmolowicz, Bickel, Carter, Franck, & Mueller, 2012; Johnson, Herrmann, & Johnson, 2015; VanderBroek, Acker, Palmer, de Wit, & MacKillop, 2016), as well as experimental demonstrations of episodic future thinking (Sze,

Stein, Bickel, Paluch, & Epstein, 2017) , preference reversals (Yi et al. 2016), and other phenomena (Chivers, Hand, Priest, & Higgins, 2016; Meredith, Sweeney, Johnson, Johnson, & Griffiths, 2016; Michaelson, de la Vega, Chatham, & Munakata, 2013). Finally, the effect sizes in the current study are mostly small. To avoid overstating the meaning of the current findings, replicating the study in future research may be necessary. As the first study to investigate the effect of mating narratives on rates of discounting and drug valuation, we believe the present study contributes new knowledge that may have substantial implications for understanding addiction and finding a potential component of future behavioral interventions that aim to treat addiction.

Conclusion

Participants were more inclined to choose the delayed but larger rewards after reading the romantic narrative compared to controls. However, the sexual narrative significantly increased their choice preference to the immediate smaller rewards. Moreover, the romantic narrative significantly decreased craving of cigarettes while the sexual narrative increased cigarette valuation. These findings suggest that mating narratives may be useful in manipulating rates of discounting, may be relevant for altering cigarette valuation and craving, and may show potential as a component of future behavioral interventions for addiction. Given the small effect sizes, replicating the study in future research will be beneficial.

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Table 1.1. Sample characteristics for Study 1 by group (N=132)

Characteristics	Frequency (%)/Mean (SD)		
	Control n= 65	Romance n= 67	P value
Male	45 (69.2)	46 (68.7)	.943
Married	20 (30.8)	33 (49.3)	.091
Education level			.234
High school diploma or equivalei	21 (32.3)	23 (34.3)	
Associate degree	15 (23.1)	7 (10.4)	
Bachelor degree	23 (35.4)	28 (41.8)	
Graduate degree	3 (4.6)	8 (11.9)	
Income			.830
Less than $9,999	5 (7.7)	2 (3.0)	
$10,000 - $29,999	20 (30.8)	25 (37.3)	
$30,000 - $49,999	19 (29.2)	15 (22.4)	
$50,000 - $69,999	11 (16.9)	12 (17.9)	
$70,000 - $89,999	5 (7.7)	8 (11.9)	
$90,000 - $109,999	3 (4.6)	2 (3.0)	
$110,000 - $139,999	1 (1.5)	2 (3.0)	
White	45 (69.2)	46 (68.7)	.954
Not-Hispanic	55 (84.6)	58 (86.6)	.939
Age	32.26 (± 7.89)	34.40 (± 9.36)	.158
Number of daily cigarettes	15.97 (± 8.27)	15.42 (± 7.21)	.684
PHQ9	6.32 (5.27)	6.37 (5.22)	.956
FTCD	5.2 (± 2.11)	5.46 (± 2.17)	.483
PANAS positive	33.20 (8.57)	35.76 (7.832)	.075
PANAS negative	16.45 (9.43)	14.61 (7.92)	.228

Baseline Discounting rates (Lnk)	-4.04 (±3.42)	-4.13 (±3.10)	.870
Baseline ED_{50} in years	1.97 (±3.97)	1.54 (3.59)	.510

Table 1.2. Sample characteristics for Study 2 by group (N=273)

Characteristics	**Frequency (%)/Mean (SD)**			
	Control n= 84	**Romance n= 114**	**Sex n= 75**	**P value**
Male	53 (63.1)	71 (61.7)	59 (77.6)	0.054
Married	37 (44.0)	45 (39.1)	25 (32.9)	0.444
Education level				0.158
High school diploma or equivalency	24 (28.6)	42 (36.5)	20 (26.3)	
Associate degree	12 (14.3)	15 (13.0)	19 (25.0)	
Bachelor degree	37 (44.0)	51 (44.3)	31 (40.8)	
Master's degree	8 (9.5)	6 (5.2)	2 (2.6)	
Doctoral degree	0 (0.0)	1 (0.9)	0 (0.0)	
Professional (MD, JD, DDS, etc.)	2 (2.4)	0 (0.0)	1 (1.3)	
Income				0.242
Less than $9,999	5 (6.0)	5 (4.3)	5 (6.6)	
$10,000 - $29,999	18 (21.4)	32 (27.8)	21 (27.6)	
$30,000 - $49,999	27 (32.1)	37 (32.2)	26 (34.2)	
$50,000 - $69,999	10 (11.9)	24 (20.9)	13 (17.1)	
$70,000 - $89,999	11 (13.1)	9 (7.8)	6 (7.9)	
$90,000 - $109,999	7 (8.3)	1 (0.9)	2 (2.6)	
$110,000 - $139,999	4 (4.8)	3 (2.6)	1 (1.3)	
$140,000 and above	1 (1.2)	3 (2.6)	1 (1.3)	
White	61 (72.6)	89 (77.4)	48 (63.2)	0.224
Not-Hispanic	78 (92.9)	107 (93.9)	66 (88.0)	0.409
Age	34.32 (9.75)	34.18 (9.07)	33.28 (8.31)	0.735
Number of daily cigarettes	15.7 (5.67)	16.04 (7.42)	15.94 (6.71)	0.927
PHQ9	7.60 (6.90)	7.44 (6.44)	6.67 (6.44)	0.636

FTCD	5.24 (1.81)	4.89 (2.22)	5.29 (1.88)	0.323
PANAS positive	31.42 (9.61)	36.18 (9.70)	36.33 (9.96)	.001
PANAS negative	19.24 (9.84)	15.44 (7.78)	14.07 (5.30)	<.001

Table 1.3. Multivariate analysis of covariance of discounting rates, cigarette valuation, and fast food craving by narrative type controlling for gender, marital status, PANAS positive, and PANAS negative scores (study 2)

Variable	Sum of Squares	*df*	Mean Squares	*F*	*P value*	*Effect Size* ω^2
Discounting Rate	92.62	2	46.31	12.23	<.001	.065
Valuation (out of pocket)	19385.38	2	9692.69	7.68	.001	.059
Valuation (gift card)	47056.08	2	23528.04	31.63	<.001	.193
QSU Factor 1	855.80	2	427.90	8.14	<.001	.028
QSU Factor 2	1321.44	2	660.72	11.09	<.001	.051

Note:
ω^2= omega squared= effect size

Table 1.4. Post hoc analysis using the Dunnett's test for Study 2 outcome measures (*N*=273)

Characteristics	Mean (SD)			
	Control *n*= 84	Romance *n*= 114	Sex *n*= 75	*P* value
Rates of Discounting (Lnk)	-5.30 (1.90)	-5.94 (1.86)*	-4.60 (2.19)*	<.001
Valuation (out of pocket)	$3.27 (4.67)	$5.04 (10.16)	$25.30 (66.5)***	<.001
Valuation ($100 gift card)	$8.03 (16.92)	$11.90 (22.65)	$40.84 (40.88)**	<.001
Cigarette Craving factor 1	26.27 (7.19)	23.63 (8.14)*	26.95 (7.63)	.007
Cigarette Craving factor 2	22.55 (8.02)	18.68 (8.29)**	23.12 (8.44)	<.001

* $p<0.05$ compared to control
** $p<0.01$ compared to control
*** $p<0.001$ compared to control

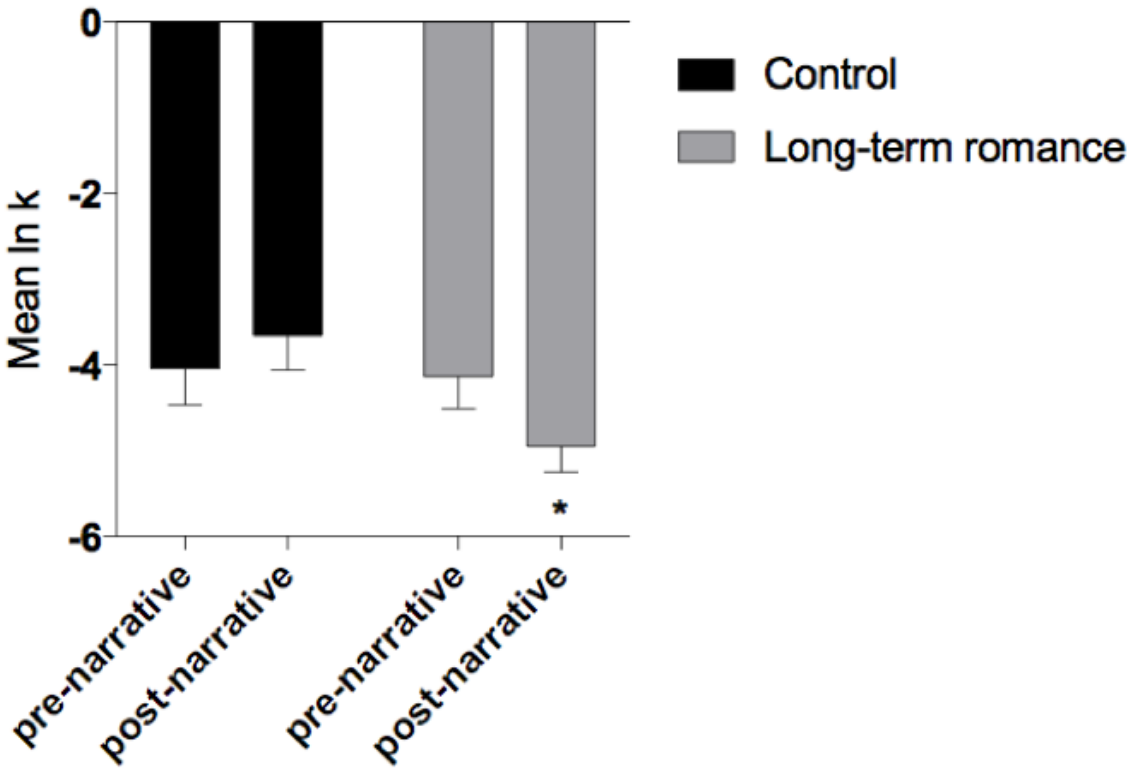

Figure 1.1. Mean discounting rates Pre- and Post- reading the mating and control narratives (Study 1)
* $p<0.05$
Error bars represent standard error.

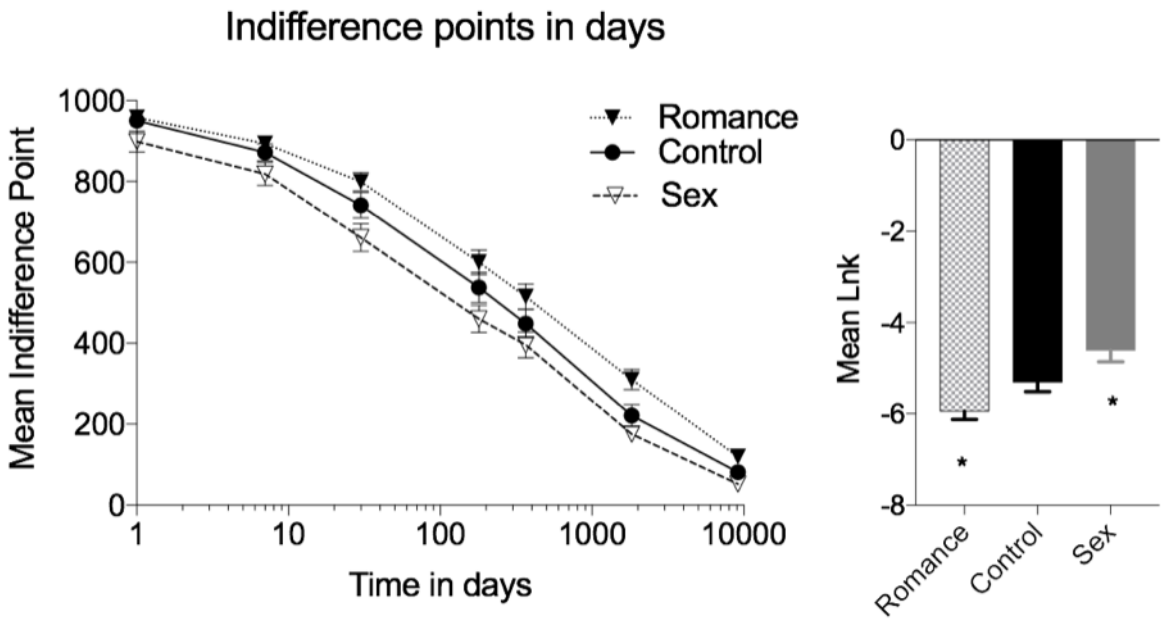

Figure 1.2. The mean delay discounting indifference points of $1000 (left) calculated for each of the seven points of time used in the adjusted amount discounting (1 day, 1 week, 1 month, 6 months, 1 year, 5 years, 25 years). Right: The mean (*M*) delay discounting rates (*lnk*) for participants in the three groups (right).

* $p<0.05$ compared to controls

Error bars represent standard error.

The x-axis in the left figure is on a log scale

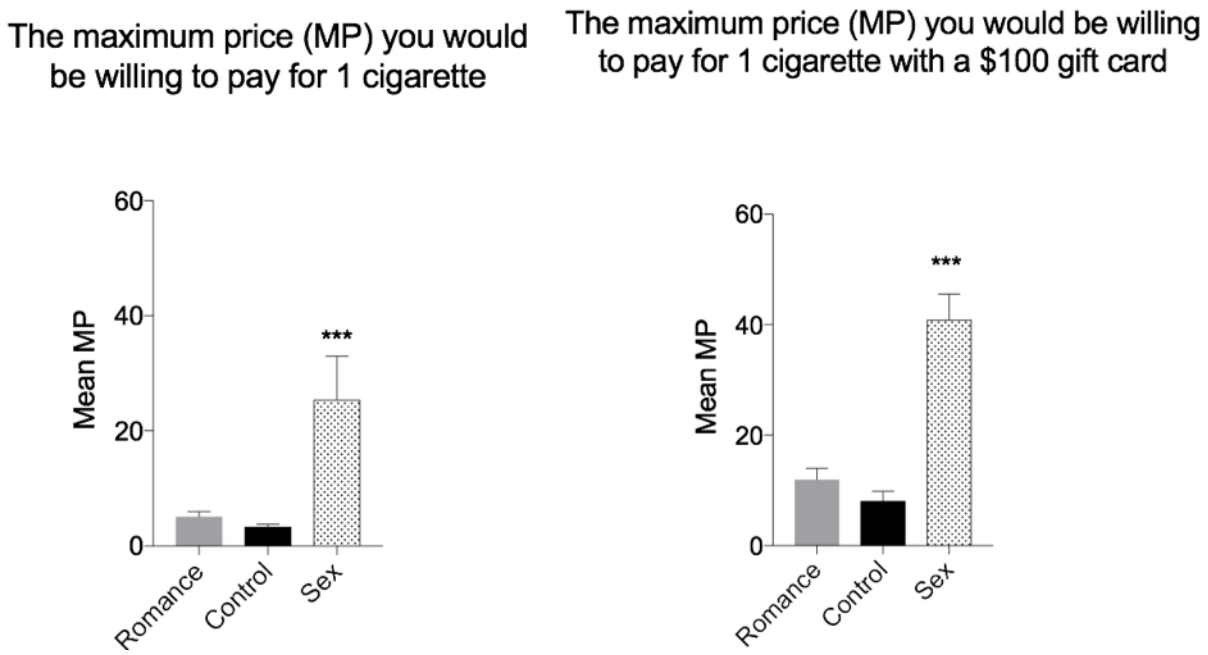

Figure 1.3. The mean maximum price (MP) participants would be willing to pay for 1 cigarette out of pocket (left) and using a $100 gift card (right) among the three groups.
***$p<0.001$ compared to control
Error bars represent standard error.

Manuscript 2

Title:

Future Thinking to Decrease Real-World Drinking in Alcohol Use Disorder: Repairing Reinforcer Pathology in a Controlled, Real-World Trial

Abstract

Alcohol addiction is a major public health problem. Based on the Reinforcer Pathology theory, expanding the temporal window of reinforcement (i.e., reducing delay discounting) using episodic future thinking (EFT) would decrease alcohol consumption. However, evidence of effectiveness in real-world settings is lacking.The current study examines the effect of remotely delivered EFT on expanding the temporal window of reinforcement and decreasing real-world alcohol consumption among individuals with alcohol use disorder (AUD). A parallel-group, randomized clinical trial performed from September 2017 to September 2019. We enrolled 94 individuals (23 females) aged 18-65 years who met the DSM-5 criteria for moderate or severe AUD and desired to cut down or quit alcohol drinking from September 2017 to September 2019. Of those, 55 individuals (59%) completed the study. Using a self-guided and computerized generation task, participants in the EFT (the intervention) group generated four positive, specific, and vivid future events and participants in the control episodic thinking (CET; the control) group generated four positive, specific, and vivid past events. Participants received 2 text messages (each included one randomly chosen episodic event from the four generated) prompting them to engage in EFT or CET daily for about 14 days. Changes in the temporal widow (i.e., discounting rates) and the number of alcoholic drinks consumed daily. After about two weeks, both rates of discounting and daily alcohol consumption were significantly lower (η_p^2=.108 and η_p^2=.137, respectively) in the intervention participants. Changes in discounting significantly predicted changes in alcohol consumption (coef. = .754, 95% CI, .299 - 1.209, p= .002). Overall satisfaction with the study approach across groups was rated as 3.96 on a 1 to 5 point scale which suggests that the current remote approach is feasible and acceptable to participants. The current findings demonstrate the relevance of Reinforcer Pathology for understanding and intervening in alcohol use disorder. The significant effect of remotely delivered EFT in reducing real-world alcohol consumption provides scientific justification to further investigate Reinforcer Pathology based interventions that expand the temporal window to change alcohol valuation and consumption. The construction of multi-component treatments that incorporate Reinforcer Pathology based interventions to systematically alter the temporal window may provide a novel intervention to reduce alcohol

consumption.

Trial Registration: clinicaltrials.gov Identifier: NCT03340051

Future Thinking to Decrease Real-World Drinking in Alcohol Use Disorder: Repairing Reinforcer Pathology in a Controlled, Real-World Trial

Introduction

The third leading cause of preventable deaths in the United States is alcohol misuse, which contributes to approximately 88,000 fatalities every year (for Disease Control, Prevention, & Others, 2014; Stahre, Roeber, Kanny, Brewer, & Zhang, 2014). Despite decades of effort developing evidence-based treatments, alcohol misuse remains one of the most problematic and enduring public health crises (Center for Behavioral Health Statistics and Quality, 2015; Sacks, Gonzales, Bouchery, Tomedi, & Brewer, 2015). Developing a new generation of theoretically-derived interventions responsive to alcohol-related problems constitutes an important clinical and scientific gap that if addressed may open innovative treatment opportunities.

Decades of work in psychology, economics, neuroscience and information sciences (Bickel, Snider, & Mellis, 2019; Bickel et al., 2017; Bickel, Wilson, Chen, Koffarnus, & Franck, 2016; Gupta & Merchant, 2017; Okamoto & Fukai, 2009; Snider, LaConte, & Bickel, 2016) has led to the emergence of a novel conceptual framework of addiction, Reinforcer Pathology, for understanding the mechanisms that determine the excessive valuation of unhealthy reinforcers such as alcohol. According to Reinforcer Pathology theory, reinforcers are integrated over a temporal window that determines the relative value of alcohol and prosocial reinforcers (Bickel et al., 2019). Specifically, with a short temporal window, reinforcers that are brief, immediate, intense, and reliable will be overvalued relative to both the delayed negative consequences associated with substance use as well as the prosocial reinforcers that are lower in intensity, variable in outcome, and accrue in value over time (such as employment, long-term health, and social relationships (Bickel et al., 2017)). From this perspective, the Reinforcer Pathology theory predicts that interventions that expand the temporal window of integration would decrease the valuation of brief, immediate, intense, and reliable reinforcers while enhancing the value of temporally extended prosocial reinforcers.

The science of human prospection provides a novel intervention (Gilbert & Wilson, 2007), Episodic Future Thinking (EFT), for expanding the temporal window of reinforcer integration. EFT is the capability to self-project and pre-experience the future (Atance & O'Neill, 2001) and has been shown to expand the temporal window as measured by delay discounting (Bulley & Gullo, 2017; Chiou & Wu, 2017; Daniel, Said, Stanton, & Epstein, 2015; Daniel, Stanton, & Epstein, 2013a, 2013b; Kaplan, Reed, & Jarmolowicz, 2016; O'Neill, Daniel, & Epstein, 2016; Peters & Büchel, 2010; Snider et al., 2016; Stein et al., 2016; Stein, Tegge, Turner, & Bickel, 2018) . Delay discounting refers to the decline in value of a reinforcer as a function of delay to its receipt. Importantly, expanding the temporal window using EFT has been shown to reduce the valuation of alcohol in a laboratory environment (Bulley & Gullo, 2017; Snider et al., 2016).

Given that no study to date has clinically examined whether expanding the temporal window with EFT reduces alcohol consumption in real-world settings we propose, in the current field trial, to test the Reinforcer Pathology theory on AUD participants' alcohol consumption in the real-world. In doing so, we will utilize a simple, low cost, widely available technology that permits both remote ecological momentary assessments (EMAs) and the delivery of ecological momentary interventions (EMIs).

Methods

Study Design

The current study is a parallel-design, randomized field trial (Figure 1) that was adapted from previously published studies (Koffarnus, Bickel, & Kablinger, 2018; Moody, Tegge, Poe, Koffarnus, & Bickel, 2018). The study included 2 study phases: (1) a baseline phase and (2) an intervention phase. The baseline phase included the consent, the baseline laboratory session, and a 7-day period of real-world monitoring (using daily self-reported EMAs). The intervention phase included an intervention laboratory session, a 14-day period of real-world intervention (using daily self-reported and biological EMAs in addition to EMIs), and a post-intervention laboratory session. Participation in the study was voluntary and all participants provided written informed consent. The study was approved by the Institutional Review

Board (IRB) at Virginia Polytechnic Institute and State University and registered with clinicaltrials.gov (NCT03340051).

Participants

We enrolled 94 individuals (23 females) from September 2017 to September 2019. Of those, 55 individuals (59%) completed the study (Figure 1). Participants were recruited from the communities of Roanoke and Blacksburg, Virginia, using newspaper advertisements, Craigslist, flyers posted in prominent public places, online advertisements, and referrals. Using a screening questionnaire (administered online, by phone or in-person), All participants were between the ages of 18 and 65 (M = 41.5, SD = 11.8), met the DSM-5 criteria for moderate or severe alcohol use disorder (defined by four or more symptom criteria [31]), and desired to cut down or quit drinking. We excluded individuals taking over-the-counter medications containing or contraindicated with alcohol, who were pregnant or lactating, who participated in any previous studies that included EFT and were conducted at the Addiction Recovery Research Center in the last 6 months, and those who had immediate plans to move out of the area. In addition, participants were excluded from the study if they met both of the following criteria: (1) scored 23 or greater on the Alcohol Withdrawal Symptom Checklist (a score indicating that medication would be likely required to manage alcohol detoxification; see [32]); and (2) were deemed inappropriate for study participation by the study physician (e.g., imminent risk of delirium tremens or withdrawal seizures). All participants who scored 23 or above on the Alcohol Withdrawal Symptom Checklist were offered access to medical care in addition to an emergency contact card for local medical facilities.

Study Measures

Baseline Phase

The baseline phase included a laboratory session and a real-world period (including once-daily self-reported EMAs). During this baseline session, participants answered demographic questions and completed a battery of assessments (including delay discounting) and questionnaires related to alcohol

use and associated behavioral cognitive processes (e.g., Beck Depression Inventory, Beck Anxiety Inventory, AUDIT, and FTND; see table 2.1).

During the real-world baseline period, daily self-reports of previous-day drinking (i.e., EMAs) were collected for about 7 days. Participants were instructed to drink as usual and were prompted via text messages to provide the number of drinks they consumed during all waking hours the day before. This occurred with no other study intervention taking place. Participants were provided with verbal instruction as well as a card with a graphic explaining standard drink sizes to promote accurate reporting of drinks. If participants did not have a cell phone or did not want to use a personal cell phone, then one was provided for use throughout the study. The study used prepaid cell phones with services through Cricket Wireless LLC, a nationwide cell phone service provider, enabling powerful usage controls and allowing us to restrict phone communication to a study phone and 911 service. Participants were compensated $1 for providing these daily reports, regardless of alcohol consumption, that was delivered electronically and transferred to a reloadable debit card (https://greenphire.com). Funds were immediately available when added. During this baseline period, participants who successfully reported their daily drinking as requested on at least 5 of the 7 days, and who reported alcohol consumption on at least two days with an average that exceeds 2 drinks a day were invited to continue in the study. The data collected during this 7-day baseline period was used to quantify baseline drinking patterns, stratify participants to groups in the intervention session, and to ensure that participants can reliably provide the data necessary for the field trial.

Intervention Phase

The Intervention phase included a laboratory intervention session, a real-world intervention period (including once-daily self-reported EMAs, thrice-daily biological EMAs and twice-daily EMIs), and a laboratory post-intervention session.

Laboratory intervention session

At the end of the baseline phase, eligible participants were invited to return to the laboratory to complete their second session (i.e., the intervention session). During the intervention session, participants

were randomized to either the active (EFT) or the control (control episodic thinking; CET) groups with a computerized algorithm(Moody et al., 2018) that biased the random assignment to balance the groups on current alcohol use (average drinks per day during the baseline 7-day period) and level of alcohol problems (i.e., AUDIT scores). Later in the study, a measure of subjective alcohol valuation (the number of drinks participants would hypothetically consume if they were free (Murphy & MacKillop, 2006)) was added to the randomization algorithm to ensure balanced groups on the valuation of alcohol as well. Participants were not made aware of the differences between the two groups. All information and instructions provided to participants were the same for both groups.

EFT (the intervention) and CET (the control) events and corresponding textual cues were generated using a self-guided, computerized generation task modified from ones used previously(Sze, Stein, Bickel, Paluch, & Epstein, 2017). EFT participants were instructed to imagine and carefully describe in detail four positive, specific, and vivid future events (big or small) which they were looking forward to at each of 4 delays in the future: 2 weeks, 1 month, 6 months and 1 year. For the CET group, participants were instructed to list and describe in detail four positive, specific, and vivid past events (big or small) that they had enjoyed in the past 12 hours, 1 day, 6 days, and 12 days. Participants in both groups were instructed to describe the events as though they were occurring in the present moment and were prompted to provide specific details of their events such as who they were with, where the event occurred, how they felt, and what was happening at the time. In addition, they were provided with examples of correct (detailed and positive) and incorrect (vague and negative) events and explanations of the differences between them to highlight the importance of positivity, vividness, and specificity when generating events.

Real-world intervention period

During the real-world intervention period, EMIs were sent twice-daily, self-reported EMAs were collected once-daily, and biological EMAs were collected thrice-daily for about 14 days.

Daily EMIs

Twice-daily EMIs (i.e., the episodic thinking events created during the intervention session) were texted to participants at 10 am and 4 pm throughout the intervention period. The daily EMIs were two of the participant's four generated episodic thinking events (active or control) provided exactly as the participant wrote them during the intervention session. The four events were used during the intervention period with two different events texted each day in a randomized order that was assigned at the start of the intervention period.

Self-reported EMAs

For about 14 days following the intervention session, daily self-reports of previous-day drinking were collected. These self-reported EMAs occurred while the study intervention was taking place. Participants were prompted via text messages to provide the number of drinks they consumed during all waking hours the day before.

Biologic EMAs

In addition to once-daily self-reported EMAs, alcohol use during the intervention phase was monitored with thrice-daily breathalyzer samples. The biologic EMAs were collected remotely using a Soberlink SL2 breathalyzer. Soberlink devices use facial recognition technology to verify identity during each breath sample submission. The Soberlink system allows for custom testing schedules and automated report settings. All participants completed breathalyzer assessments 3 times per day for about 14 days. Participants were asked to choose an assessment time shortly after they usually awaken, shortly before they go to bed at night, and once throughout the day. Chosen times were separated by at least 6 hours. This ensured that the first and last EMAs each day were at least 12 hours apart, and the EMAs were distributed throughout the waking hours. Participants were reminded via text message when a sample was to be collected, and samples were accepted about 15 minutes before the scheduled time and 60 minutes after the scheduled time. The breath results are wirelessly transmitted in real-time to a centralized, secure website where the data were available to research staff. Both groups received a $1 payment (delivered electronically and transferred to a reloadable debit card) for each breathalyzer result submitted (a maximum of $3 daily for 3 breath samples submitted on time), regardless of the result of the test. These

payments were to encourage participants to complete the biologic EMAs, even if they had consumed alcohol that day. The biologic EMAs were used to assess the reliability of the self-reported EMAs. In addition, participants were compensated $50 for returning the Soberlink device and the study cell phone if used.

In-laboratory post-intervention session

After completing the intervention session and the real-world intervention period, participants were invited to complete a post-intervention session where they completed a battery of assessments similar to those administered during the baseline session (Supplement 2). In addition, at the end of this session, participants completed a 10-item brief intervention acceptability questionnaire (Koffarnus et al., 2018; Moody et al., 2018) where they rated the satisfaction, effectiveness, and ease of use of the study components (e.g., Soberlink devices, the payment system, the phones, the scheduled requirements, etc.; Table 2.5) and the overall satisfaction with the intervention on a scale from 1 to 5 where 1 = very (dissatisfied, difficult, inconvenient) and 5 = very (satisfied, easy, convenient).

Statistical Analysis

We used a medium/high effect size (f = 0.4) to inform the sample size of the study. A total of 52 participants were needed to complete the study assuming a type 1 error rate of 0.05, 80% statistical power, and pre- and post-measure based on an ANCOVA comparing the intervention while using the baseline measure as a fixed-effect covariate in the analysis.

Prior to analysis, discounting data collected using the adjusting amount task was subjected to diagnostic criteria (Johnson & Bickel, 2008) to ensure systematic and valid data. The data sets excluded from the discounting analysis (N = 4; 1 EFT and 3 CET) were included in all other analyses. The frequency of non-systematic discounting data did not differ significantly by group (χ^2 (1, 55) = 1.33, p = .265).

The primary measure of alcohol use pre- and post-intervention was determined using the self-reported EMAs. This outcome was coded as a continuous variable once per day as reported by participants and averaged throughout the baseline period for a pre-intervention score and throughout the

intervention period for a post-intervention score. The primary analysis for the discounting rates, alcohol use, and alcohol craving was the analysis of covariance (ANCOVA) with pre- to post-intervention change score as the dependent variable, episodic thinking as the between-subjects factor, and pre-intervention (baseline) scores as a covariate(Hendrix, Carter, & Hintze, 1978) with a Sidak pairwise correction. In addition, to further investigate the Reinforcer Pathology, stepwise multivariate linear regression analysis was run to assess the ability of discounting rates to predict changes in alcohol consumption (regardless of groups). The stepwise multivariate linear regression model included alcohol consumption change score as the dependent variable and discounting rates change score and demographics (i.e., age, gender, race, income, education, marital status and family history of addiction) as independent variables.

To verify the reliability of self-reported EMAs (i.e., daily drinks), Pearson product-moment correlations were run between the self-report and the biologic (i.e., the BrAC samples) EMAs among the study sample, among the EFT group alone, and among the CET group alone. The BrAC samples were coded as a continuous variable thrice-daily as recorded by the Soberlink breathalyzers and was scored by averaging the submitted samples throughout the intervention period. Overall intervention compliance rates were examined separately for self-report and biologic EMAs and were calculated by averaging the percentage of samples obtained successfully per participant.

Demographic characteristics and baseline measures of alcohol use, rates of discounting, and scores of Beck Depression Inventory, Beck Anxiety Inventory, AUDIT, and FTND were compared between groups using independent-sample *t*-tests and Chi-square tests (Fisher's Exact test as appropriate) for continuous and categorical variables, respectively. Multivariate general linear regression was used to compare measures of acceptability and effectiveness of the intervention between groups. All analyses were conducted in SPSS 26 (IBM Analytics, Armonk, NY) at a significance level of 0.05.

Results

A total of 55 participants completed the post-intervention session and were included in the final analysis (Figure 1). *T*-tests and *Chi*-squares test indicated no significant differences for any of the baseline

characteristics (demographic measures) between groups (table 2.2) and the baseline outcome measures (e.g., alcohol use, rates of discounting, alcohol craving, scores of Beck Depression Inventory, Beck Anxiety Inventory, AUDIT, and FTND; Table 2.3).

The ANCOVA analyses (Table 2.4) indicated a significant main effect of group on the number of daily drinks consumed, with a significant decrease in number of drinks among participants in the EFT group (M = -2.436, SD = 2.92, p = .006, η_p^2 = .137) compared to the control group (M = -.521, SD = 2.52; Figure 2). Moreover, a significant main effect was found for rates of discounting measured using the $100 adjusting amount discounting task, with a significant decrease in discounting rates among participants in the EFT group (M = -.541, SD = 1.46, p = .020, η_p^2 = .108) compared to the control group (M = .448, SD = 1.39; Figure 2). However, no significant difference was observed in factors of alcohol craving among the two groups (Table 2.4). The stepwise multivariate linear regression analysis indicated that changes in discounting rate significantly predicted changes in alcohol consumption (coef. = .754, 95% CI, .299 - 1.209, p = 0.002) even when controlling for age, gender, race, income, marital status, education, and family history of addiction.

A significant correlation was observed between the self-report and biologic EMAs (r = .530, n = 55, p < .001) across groups, among the EFT group only (r = .478, n = 29, p = .009) and among the CET group only (r = .525, n = 26, p = .006) suggesting a valid and reliable self-reported daily consumption of alcohol among the study sample. The average percent of daily self-reported EMAs submitted was 93.5% and the average percent of breath alcohol samples submitted was 86.0% per participant suggesting high compliance rates among the study sample.

No significant differences were found between groups for any of the intervention acceptability questions (Table 2.5). Overall satisfaction across groups was rated as 3.96 on a 1 to 5 point scale which suggests that the current remote approach is feasible and acceptable to participants.

Discussion

This clinical field trial has for the first time demonstrated, using the Reinforcer Pathology theory,

that expanding the temporal window decreases valuation of alcohol in real-world settings. The Reinforcer Pathology theory builds on decades of behavioral economics work in addiction (Bickel et al., 2019, 2017), and is the first theory to formalize the role of the temporal window as a determinant in addiction as well as a key target for interventions. The current findings of significant effect of remotely delivered EFT in expanding the temporal window and reducing real-world alcohol consumption provide scientific justification to further investigate interventions capable of altering the temporal window, including EFT, to change alcohol valuation and consumption. The current findings corroborate and extend upon previous laboratory findings of the effect of EFT in expanding the temporal window among individuals with AUD (Bulley & Gullo, 2017; Snider et al., 2016) and demonstrate a feasible and effective method to implement EFT intervention in real-world settings. Note that expanding the temporal window in the current study diminished but did not necessarily eliminate the value of alcohol suggesting the importance of the construction of multi-component treatments that incorporate Reinforcer Pathology based interventions to produce greater effect in reducing alcohol consumption. These findings are important given the need for new and innovative interventions that could aid the currently available treatments to decrease the persisting high annual rates of alcohol-related problems in the United States and worldwide.

The current study used technology and advanced data collection tools to validate and improve the accuracy of measurements used to assess alcohol consumption. The current findings of high compliance in submitting the daily self-report EMAs (93.5%) and the breathalyzer assessments (86.0%), and the high ratings of satisfaction, effectiveness, and ease of use for the study components (e.g., Soberlink devices, phones, the payment system) across groups expand upon previous studies using technology-based interventions for AUD (Alessi & Petry, 2013; Carroll et al., 2009; Gustafson et al., 2014; Hester, Delaney, Campbell, & Handmaker, 2009; Hester, Squires, & Delaney, 2005; Koffarnus et al., 2018; Kypri et al., 2004; Moody et al., 2018) by investigating the feasibility and effectiveness of using smartphone technology to remotely deliver EFT. This combination of high efficacy, high compliance, and positive ratings of acceptability suggest a potential clinical benefit of using technology-based methods to deliver and implement the use of EFT among individuals with AUD.

As a proof-of-concept trial testing the Reinforcer Pathology concept using self-report and biologic EMAs and daily EMIs, the sample size used in the current study might limit the generalizability of the findings. However, this limitation is attenuated by the large effect size associated with the reduction in alcohol consumption (η_p^2 = .137). When making clinical recommendations to individual patients, a large effect size among a smaller sample may be more useful than a small effect size in a large number of participants (Williams, 2010). The current study has some other potential limitations. The participants were mostly non-hispanic and male. Future research with larger samples and broader populations would demonstrate the generality of these findings. In addition, the current study design limited our ability to establish a causal relationship between expanding the temporal window and decreasing alcohol consumption in real-world. However, the results of the stepwise multivariate regression indicating that the changes in the temporal window are a predictor of changes in alcohol consumption might suggest directionality. Future longitudinal studies tracking changes in the temporal window and alcohol consumption across longer time frame might be beneficial to address the cause-effect relationship.

Conclusion

To our knowledge, the current study is the first to examine the concept of Reinforcer Pathology and investigate the feasibility and effectiveness of remotely expanding the temporal window using EFT to decrease alcohol consumption in real-world settings. In the current study, the EFT expanded the temporal window and decreased alcohol consumption. In addition, the remote approach was considered feasible and acceptable by participants. We believe the present study contributes new knowledge that has tangible implications to scientifically understand and better define novel interventions that have the potential to be clinically deployed to improve currently available treatment outcomes.

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Table 2.1. Measures collected at baseline.

Measure	Description
Demographics	Including sex, age, race, ethnicity, income, marital status, education level, and others
Adjusting-amount discounting ($100)	A standard method of obtaining a discount rate (Du, Green, and Myerson 2002; Mazur 1987) that estimates indifference points between a smaller yet more immediate amount of money and $100 that would be received after a discrete duration of time. The current task utilized the following delays: 1 day, 1 week, 1 month, 6 months, 1 year, 5 years, and 25 years. Across six trials within each delay, the immediate amount was adjusted by an amount of half that of the previous adjustment until an indifference point was reached (see Du, Green, & Myerson, 2002). The indifference point reveals the extent to which the delayed $100 has been discounted (e.g., an indifference point of $40 indicates that the delayed $100 has been discounted by 60%). Discounting curves are fit using the following hyperbolic equation, $V=A/(1+kD)$ in which V refers to the discounted value of a delayed reward; A represents the amount of the delayed reward; D equals the delay of the award, and k is a derived parameter that represents the delay-discounting rate [41]. A higher *k-value* means a steeper discounting curve (higher discounting rates) and greater impulsivity, while a lower k value represents a shallower discounting curve (lower discount rates) and less impulsivity.
Beck Depression Inventory- 2nd Ed. (BDI II)	A 21-item questionnaire that assesses the intensity of depressive symptoms (Beck et al. 1996). Each item is rated on a four-point scale ranging from 0 to 3; the BDI-II is scored by summing the rating for each question. Scores range from 0 to 63: scores of 0-13 may be interpreted as minimal depression; 14-19 as mild depression; 20-28 as moderate depression; 29-63 as severe depression.
Beck Anxiety Inventory	A 21-item questionnaire that assesses the intensity of anxious symptoms (Beck et al., 1988). Each item is rated on a four-point scale ranging from 0 to 3; the BAI is scored by summing the rating for each question. Scores range from 0 to 63: scores of 0-9 may be interpreted as normal or no anxiety; 10-18 as mild or moderate anxiety; 19-29 as moderate to severe anxiety; 30-63 as severe anxiety.
Alcohol Use Disorders Identification Test (AUDIT)	A 10-item self-report questionnaire developed by the World Health Organization that assesses alcohol use, drinking behaviors, and problems related to alcohol use (Saunders et al., 1993). AUDIT scores range from 0 to 40 where 0 indicates no alcohol use. AUDIT scores between 8 and 15 indicate medium levels of alcohol problems and scores of 16 and above are associated with high levels of alcohol-related problems.
Alcohol craving Questionnaire- Short form- Revised (ACQ-SF-R)	A self-administered, 5-point Likert scale used to measure acute alcohol craving. It contains 12 items adapted from the 47 original items on the Alcohol Craving Questionnaire (ACQ-NOW). The items were selected from the initial validation study (Singleton, et al., 1996). The ACQ-SF-R generates craving values for four subscales (compulsivity, expectancy, purposefulness, and emotionality) as well as a total measure of craving by summing the raw scores for each item and dividing by 12.
Fagerstrom Test for Nicotine Dependence (FTND)	Assesses the intensity of **physical addiction** to nicotine (Fagerström 2012). FTND is a widely used six-item questionnaire that generates a score between 0 and 10. A score of 1-2 suggests very low dependence on nicotine; 3-4 suggests low dependence; 5 suggests medium dependence; 6-7 suggests high dependence; 8-10 suggests very high dependence (Heatherton and Kozlowski 1992).

Table 2.2. Sample Characteristics by Group ($N = 55$)

Characteristics	EFT ($n = 29$)	CET ($n = 26$)	P value
Age, Mean (SD), y	41.59 (11.68)	38.42 (11.37)	.907
Age of first alcohol abuse, Mean (SD), y	17.07 (4.86)	15.46 (3.87)	.873
Male sex, No. (%)	25 (86.2)	21 (80.8)	.428
Race, No. (%)			.666
White	15 (51.7)	12 (46.2)	
Black or African American	12 (41.4)	11 (42.3)	
Other	2 (6.8)	3 (11.5)	
Non-Hispanic or Latino ethnicity, No. (%)	[a] 27 (93.1)	26 (100)	.269
Marital status, No. (%)			.753
Single	19 (65.5)	19 (73.1)	
Married	4 (13.8)	2 (7.7)	
Other	6 (20.6)	5 (21.7)	
Education level, No. (%)			.577
High school or less	12 (41.3)	13 (50)	
Some college or higher	17 (58.6)	13 (50)	
Income, No. (%)		[a]	
Less than 9,999	10 (34.5)	12 (46.2)	.504
$10,000 - $29,999	11 (37.9)	11 (42.3)	
$30,000 - $49,999	5 (17.2)	2 (7.7)	
$50,000 and greater	3 (10.3)	0 (0.0)	
Family history of addiction, No. (%)			.294
No	5 (17.2)	7 (26.9)	
Yes	24 (82.8)	19 (73.1)	

[a] One participant chose not to report

Table 2.3. Baseline measures by Group ($N = 55$)

Characteristics	*Mean (SD)*		
	EFT	CET	*P* value
Daily drinks	6.63 (3.58)	6.71 (3.57)	.934
Delay discounting rate, ln *k*	-3.20 (2.03)	-3.65 (2.83)	.516
AUDIT	21.69 (6.96)	23.69 (6.49)	.276
Beck Depression Inventory	12.83 (9.47)	12.00 (8.66)	.736
Beck Anxiety Inventory	11.17 (13.42)	15.85 (13.54)	.205
Craving			
Compulsivity	3.25 (.76)	3.14 (.83)	.614
Expectancy	4.00 (.68)	3.73 (.88)	.229
Purposefulness	3.21 (.69)	3.47 (.70)	.205
Emotionality	3.74 (.83)	3.58 (.80)	.203
Cigarette smokers, No. (%)			.457
No	8 (27.5)	5 (19.2)	
Yes	21 (72.4)	21 (80.8)	
Cigarettes Smoked Daily *Mean (SD)*	15.35 (10.57)	13.45 (8.31)	.151
FTND	3.86 (3.29)	4.19 (2.87)	.695

Table 2.4. Analysis of Covariance (ANCOVA) Models for Effects of Group on changes on daily drinks, discounting rates, and alcohol Craving ($N = 55$)

Variable	Sum of Squares	*df*	Mean Squares	*F*	*P value*	*Effect Size* (η_p^2)
Daily drinks	50.990	1	50.990	8.275	.006	.137
Delay discounting rate, ln *k*	9.304	1	9.304	5.806	.020	.108
Craving (ACQ-SF-R)						
Compulsivity	2.801	1	2.801	3.805	.057	.072
Expectancy	.039	1	.039	.111	.741	.002
Purposefulness	.238	1	.238	.534	.469	.012
Emotionality	.662	1	.662	1.346	.252	.027

Note:
η_p^2 = Partial eta squared = effect size

Table 2.5. Intervention acceptability questions and average responses by Group ($N = 55$)

Characteristics	*Mean (SD)*		
	EFT	CET	*P-value*
How satisfied are you with the ability of the treatment (used in this study) to help reduce your alcohol use?	3.97 (1.017)	3.64 (1.075)	.259
How difficult is it to adhere t*o the scheduled requirements?*	4.34 (.721)	4.04 (.735)	.131
How convenient is it to use the SOBERLINK device?	4.17 (1.167)	3.96 (1.207)	.514
How convenient is it to use a cell phone to communicate with us?	4.59 (.907)	4.60 (.645)	.950
How convenient is it to use the debit card system to receive payments?	4.45 (1.242)	4.20 (1.258)	.470
How helpful are the payments in motivating you to quit drinking?	3.31 (1.198)	3.80 (1.00)	.112
How helpful is the breathalyzer feedback to motivate you to quit drinking?	3.38 (1.321)	3.72 (1.061)	.306
How confusing or clear is the payment system used in this study	4.76 (.511)	4.64 (.638	.452
How likely would you be to recommend this treatment to a friend or relative who would like to quit using alcohol?	4.00 (1.225)	4.20 (1.155)	.542
Taking all things into account, how satisfied are you with this treatment?	3.97 (1.29)	3.96 (1.098)	.987

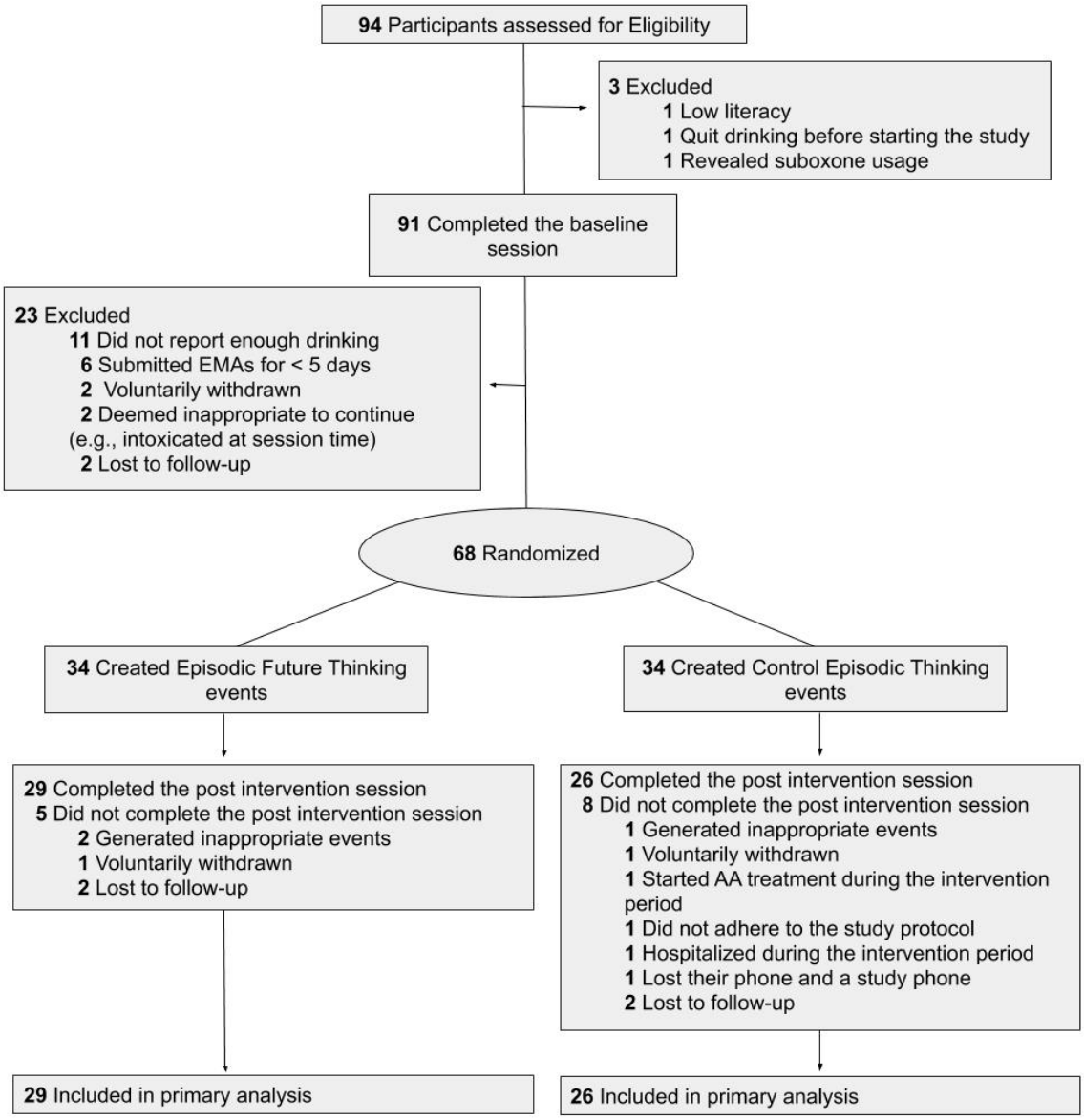

Figure 1. Flow chart presenting the progress of the study participants throughout the study

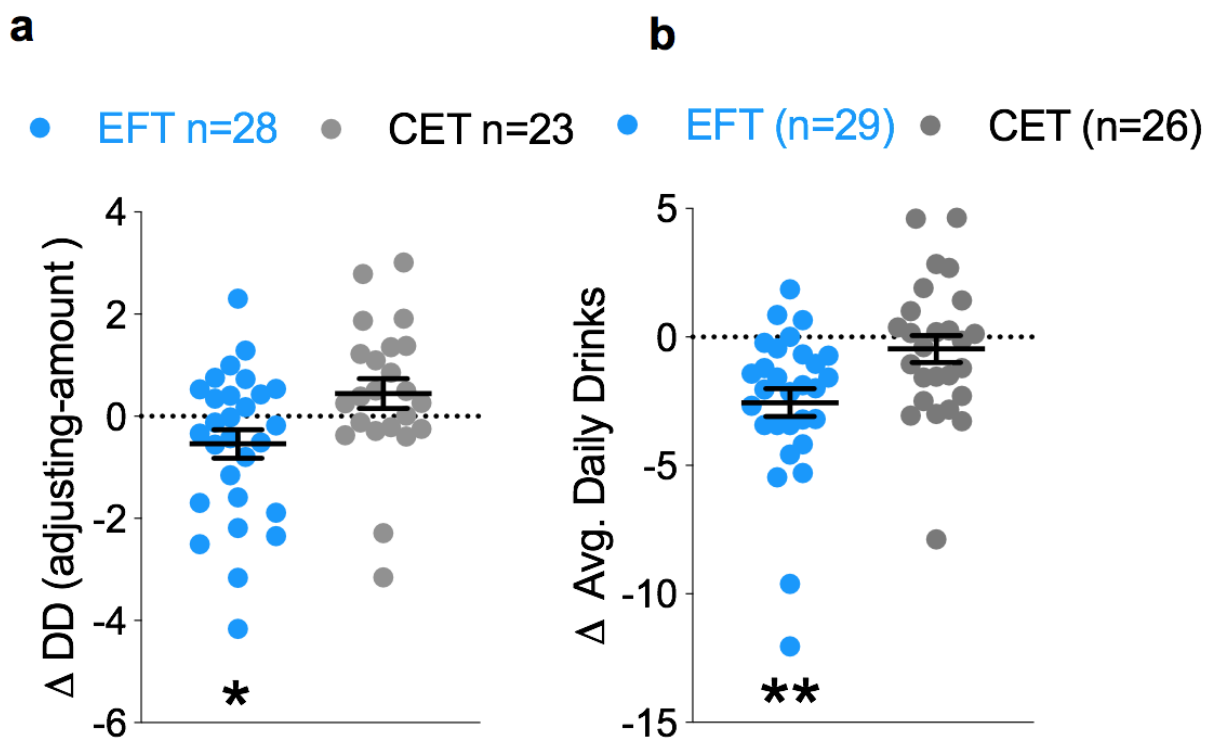

Figure 2. Consistent with Reinforcer Pathology, Episodic Future Thinking significantly decreased (a) rates of discounting as measured by a $100 adjusting amount task; and (b) real-world alcohol consumption as measured by self-reported EMAs compared to Control Episodic Thinking.

Summary and Conclusion

According to the Reinforcer Pathology theory, reinforcers are integrated over a temporal window that determines the relative value of alcohol and prosocial reinforcers (Bickel et al., 2019). Specifically, with a short temporal window, reinforcers that are brief, immediate, intense, and reliable will be overvalued relative to both the delayed negative consequences associated with substance use as well as the prosocial reinforcers that are lower in intensity, variable in outcome, and accrue in value over time (such as employment, long-term health, and social relationships (Bickel et al., 2017). In contrast, individuals with an extended temporal window (i.e, can imagine and consider outcomes further in the future) will place greater value on future rewards and therefore regard the negative consequences of harmful brief intense reinforcers (e.g., drugs) and the positive future rewards of prosocial activities leading to better decision making and less valuation of drugs. From this perspective, the Reinforcer Pathology theory predicts that interventions that alter the temporal window of integration would alter the valuation of brief, immediate, intense, and reliable reinforcers while enhancing the value of temporally extended prosocial reinforcers. The findings reported in the current research are consistent with the Reinforcer Pathology Theory.

In the first study expanding the temporal window using the romantic narrative was associated with less craving of cigarettes. However, shortening the temporal window using the sexual narrative was significantly associated with increased cigarette valuation. These findings suggest that mating narratives may be useful in manipulating the temporal window (i.e., rates of discounting), may be relevant for altering cigarette valuation and craving, and may show potential as a component of future behavioral interventions for addiction.

In the second study, we examined the the Reinforcer Pathology theory and investigated the feasibility and effectiveness of remotely expanding the temporal window using EFT to decrease alcohol consumption in real-world settings. EFT expanded the temporal window and decreased alcohol

consumption in the real world. In addition, the remote approach was considered feasible and acceptable by participants.

Together, these investigations support the Reinforcer Pathology theory and demonstrate its relevance for understanding and intervening in addiction. The current findings contribute new knowledge that has tangible implications to scientifically understand and better define novel Reinforcer Pathology based interventions that expand the temporal window to change drug valuation and consumption. The construction of multi-component treatments that incorporate Reinforcer Pathology based interventions to systematically alter the temporal window may provide a novel intervention to reduce alcohol consumption.

APPENDICES

APPENDIX 1

IRB Permission Letter for Manuscript 1

MEMORANDUM
DATE: November 9, 2016
TO: Warren K Bickel, Jeffrey S Stein, Liqa Athamneh, Kirstin Gatchalian, Sarah E Snider, Elan Samuel Perry, Alexander G Bianco, Mikhail N Koffarnus, Brian Brown, Patsy Ann Marshall, et. al.

FROM: Virginia Tech Institutional Review Board (FWA00000572, expires January 29, 2021)

PROTOCOL TITLE: The effect of fear and mating scenarios on discounting gains and losses
IRB NUMBER: 16-983
Effective November 9, 2016, the Virginia Tech Institution Review Board (IRB) Chair, David M Moore, approved the New Application request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents. Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others. All investigators (listed above) are required to comply with the researcher requirements outlined at http://www.irb.vt.edu/pages/responsibilities.htm (Please review responsibilities before the commencement of your research.)

PROTOCOL INFORMATION:
Approved As: Exempt, under 45 CFR 46.110 category(ies) 2
Protocol Approval Date: November 9, 2016
Protocol Expiration Date: N/A
Continuing Review Due Date*: N/A

APPENDIX 2

Manuscript 1- Mating Narratives

Instructions: Please carefully read the following scenario. As you're reading the scenario, try to put yourself in the shoes of the main character and experience the emotions that they are feeling.
****

MATING (Romance)

Imagine that you are on vacation with your friends on a tropical island. It's late in the afternoon and you are sitting on the beach on a pleasant summer afternoon, sipping an exotic drink. The air is warm and pleasant, and you watch the waves as the sun begins to set. You have a book open, but you're not really reading it. Instead, you look around, relaxed and daydreaming. As you watch the people strolling by on the soft sand, you notice that everyone seems to be in a particularly good mood.

From behind you, you hear a voice say: "Wow, isn't that the most beautiful sunset you have ever seen?"

When you turn around, you are surprised to see that it's coming from a particularly attractive woman whom you have seen before. You remember noticing her a few days earlier at the hotel when your eyes locked across the lobby. Since that time, you've seen her several times, but you have never had a convenient opportunity to talk with her.

Now she is standing right in front of you, and smiling warmly. "Mind if I join you for a few minutes?" she says. At first you feel a bit awkward, but as you begin to talk, you realize that you feel incredibly comfortable with her. You share your thoughts about your week on the island, and you are both a little sad that your time in paradise hasn't been as exciting as you had hoped. Up close, she is even more attractive and charming than you remember. And she is wonderful to talk to. You find that everything she says is somehow fascinating, and you notice that when you talk, she listens carefully to everything you say.

An hour passes very rapidly, and she notices that she's late for dinner with her friends. She suggests that maybe she'll just skip dinner with them and stay here with you, if you still want company. After all, she sees them all the time, but right now she's having a really nice time with you. You are only too glad to prolong the conversation. It is clear that she is enjoying your company immensely.

She suggests that the two of you go grab something to eat. Walking together, you notice that she's walking close to you and comfortably touching you on the arm when you say something that makes

her laugh. When she's around you, your senses become heightened. Even when her hand touches yours by accident, you feel a tingle and a rush of excitement. You quickly glance at her eyes, waiting for her to look at yours. When she does, both of you smile and look away.

You end up in a little restaurant near the beach, and the two of you sit in a dark romantic corner in the back. By the candlelight, you notice the pleasant and soothing aromas from the kitchen. As the evening goes on, you realize you are having an absolutely wonderful time with this person, and that she is feeling the same way. The two of you order a dessert together and decide to share it. She suggests that after dinner, both of you should go for a walk on the beach. You have been dreaming about someone asking you that very question all week.

As you stroll out onto the sand, she reaches for your hand. You softly squeeze her hand in yours and your eyes meet once again. It's a little windy and you get closer to her. Her body feels warm, and she puts her head on your bare arm.

You can feel that your heart is beating faster, and you feel excited. The sand feels cool and soft against your feet. A wave comes crashing on the beach and you both lightly trip and fall as you try to run away. Sitting in the sand and still holding her hand, both of your eyes lock again and your heart feels like it's about to stop. As you look at her beautiful face, her eyes were talking to yours, she is as happy as you are, if not more. Even though it all started few hours ago, you both started talking about your plans to stay in contact and meet again. You both smiled while talking about being together, cuddling on the couch, waking up to good morning kisses, having arguments, making up after. You talked about cooking your favorite food, smiling for no reason, annoying each other when you are bored, and never leaving each other's side. You are deeply daydreaming of a long-term relationship. As you look at her beautiful face, her hand moves up to caress the back of your neck, you squeeze her body tighter, and you can feel yourself getting excited as you begin to think that this might be one of many memorable nights of your life TOGETHER...

MATING (Sex)

Imagine that you do not have a partner in life and you are on vacation with your friends on a tropical island. It's late in the afternoon and you are sitting on the beach on a pleasant summer afternoon, sipping an exotic drink. The air is warm and pleasant, and you watch the waves as the sun begins to set. You have a book open, but you're not really reading it. Instead, you look around, relaxed and daydreaming. As you watch the people strolling by on the soft sand, you notice that everyone seems to be in a particularly good mood.

From behind you, you hear a voice say: "Wow, isn't that the most beautiful sunset you have ever

seen?"
When you turn around, you are surprised to see that it's coming from a particularly very attractive woman whom you have seen before. You remember noticing her a few days earlier at the hotel, she has an extremely attractive body that is physically to your liking. She has beautiful lips and hips, perfect legs and very smooth skin. Since that time, you've seen her several times and imagined yourself having an intimate sexual relationship with her but you have never thought that you will ever have an opportunity to do so.

Now she is standing right in front of you, and smiling warmly. "Can you help me please?" she says. "Oh, yes, sure, how can I?" and before you finish your sentence she puts her arms around you and whispers softly in your ears: "Can you please take me to my room? I drank three glasses of beer and need your help to find my room" she says. Before you answer she handles you her room keys with the room number written on the outside. At first, you feel a bit confused, but as you look at her body up close, she is even more attractive than you remember. "who would say no to this?" you think to yourself, "You have been dreaming about this moment for days now".

As you walk together, you felt a volcano of near euphoric erotic energy erupting inside you just from looking at her body through her loose-fitting sundress and feeling it touching yours. Deep down you hope that you are not the only one feeling this way. "I find you so attractive," she says while leaning on you, "I noticed you a few days ago and wanted to invite you to my room since then" she added. You walk filled with excitement but without saying a word.

A few minutes later, you arrive at her room, you open the door, let her in and ask her if she needs anything else before you leave. she walks close to you and comfortably touches you and you feel a tingle and a rush of excitement. The more she comes closer to you the more you realize that you will have an absolutely wonderful night with this person and that she is feeling the same way. The two of you come closer to each other and you cannot get your eyes off her beautiful lips and body. She suggests that you close the door and come in. You have been dreaming about her asking you that very question all week.

As you turn your back to close the door, she walks over to you and put her arms around you and kisses your neck from the back. You softly close the door and turn around to get closer to her. She can feel that your heart is beating faster, and you feel excited. Her body feels warm and soft against yours. You pull her from her shirt, approach her, softly and gently, reaching your hand out to her, and she reaches upward to you, pulling you down. You embrace your cheeks touch. You feel the velvet softness of her, you smell the rich perfume, you run your hands through her hair, clasping her neck and pulling her face towards you. You gaze at her lips. You gaze into one another's eyes, you know exactly what she is thinking. Both of your eyes lock again and your heart feels like it's about to stop. As you look at her beautiful body, her hand moves up to caress the back of your neck. You can feel your hairs begin to tingle. You lean in and the tip of her nose slowly touches yours as you continue to wander in each other's gaze. Finally, you close your eyes and her soft lips slowly touch yours for the first time. Your embrace is flowing with the kind of desire that you

have never felt. You squeeze her body tighter, and you can feel yourself getting excited as you begin to think that this might be one of the most memorable nights of your entire life.

CONTROL (Keys)

Imagine that it's Tuesday afternoon. You're hanging out at home doing some important work, but it's getting boring and you're feeling tired. You know that you still have a lot to do but you want to go to the supermarket before it's too late, so you decide to call it a night and go to the store.

As you go to get your keys from the counter, you don't see them there. The keys are nowhere in sight. Thinking that it's a little awkward, you feel your pockets. No keys in there either. You try to think back to where you last saw the keys, but you can't remember. You know you had them earlier yesterday, and you're usually pretty good about leaving your keys right on the counter.

You sometimes put your keys in your backpack, so that seems the logical place to look. You search through your bag, Books, folders, pens, but no keys. You turn the bag upside down and shake it. Nothing but junk. Now you start getting a little annoyed. Where the heck are your keys? You decide to search around the house. You look all around your desk. You open the drawers. You search deep in the drawers. But they're not anywhere. You look through your bedroom floor, but all you find is junk.

You are in no hurry as you look through the laundry. Maybe they're in another pocket somewhere? You find some pieces of paper, but no keys. Feeling tired, you go into your closet and start throwing things to the floor. No keys. You run to the kitchen and start looking on the counters. You open all the cupboards and drawers. You have no idea why the keys would be there, but you need to look somewhere. In fifteen minutes, your kitchen looks like a mess. But still no keys!

You are feeling really tired and sleepy at this point. You think back to when you last remember having the keys and try to retrace your steps. You clearly remember having them earlier, but you just don't know where you put them.

Remembering that you had gone outside to take out the garbage earlier, you stroll out into the driveway. Maybe the keys fell out there? You look in the grass, the bushes, underneath cars. You see nothing. You think to yourself: did I really lose my keys? How did they disappear? You knew this was coming sometime, but why now? As you walk back inside the house, you start thinking about what you need to do if you have lost your keys.

You plop onto your living room couch. Sighing, you look back to the counter where you

normally put your keys. To your astonishment, there they are. Your keys are on the counter! How could you have missed them? You run over there to check it out. You smile. Something like this always happens to you. You leave your keys on the counter and decide to stay home and finish your work instead of going to the store.

APPENDIX 3

Informed Consent for Participants In Research Projects Involving Human Subjects

Title: Episodic Thinking (ET) and alcohol consumption
Protocol: 15-955
Principal Investigators: Warren K. Bickel, Ph.D. Institution: Virginia Tech Carilion Research Institute

Purpose of the Study
You have been asked to come to the Virginia Tech Carilion Research Institute (VTCRI) because you may qualify for this study. Your participation in this study will help us learn more about an intervention for alcohol use.

Organization and Funding Source
This study is being conducted by the VTCRI and will be funded by the National Institute on Alcohol Abuse and Alcoholism.

Number of Participants
We will enroll up to 200 participants in this study.

Participation
To participate in this study, you must be 18-65 years old, meet the criteria for alcohol dependence, and have a desire to quit or cut down on your drinking. Pregnant women are not eligible for this study, and a urine screen will be collected from all females to test for pregnancy at the beginning of the study. Individuals who participated in any previous studies that include Episodic Thinking (ET) and conducted in ARRC in the last 3 months, and participants using prescribed or over-the-counter medicines containing alcohol will also be excluded from participation.

To determine if it is safe and appropriate for you to join this study, we will ask you to complete several questionnaires. We may stop your participation if there is evidence that you have a current unstable medical illness and/or an unmanaged psychiatric or neurological disorder. We will stop your participation if your answers or performance suggest that it is not safe and appropriate for you to continue in the study. Violation of research center policies may result in the research team withdrawing you from the study. We may also stop your participation if you do not or are unable to complete any of the study procedures. We may also stop an ongoing session, or end your participation in the study because we have collected all the information we need.

You are free to stop your participation at any time. You may talk with other people about your decision to participate in this study, although we suggest avoiding confirming participation in this study to maintain confidentiality. You do not have to answer any questions that make you feel uncomfortable. There are no “right” or “wrong” answers; we want you to answer the questions honestly and

thoughtfully. If it is safe and appropriate for you to continue in the study, you will then complete questionnaires and computerized tasks that will measure some of your preferences and abilities.

Description and Procedures

This study will require you to complete approximately 4 visits to the VTCRI including today's consent session. These sessions will be approximately 1 hour each. We will ask you some questions to make sure participation in the study is safe for you. We will also collect information (e.g. age, education) from you that we need to analyze our data. We will give you a detailed description of what it will be like to be in the study and answer any questions you have.

You will be asked to provide daily self-report assessments of previous-day drinking over a cell phone for a 7-day period. You will then be invited to return to the laboratory to be provided with a SOBERLINK breathalyzer and given instruction in its use. You will also be provided with a prepaid cell phone (if necessary) and you will receive a $50 study completion bonus at the end of the study provided these devices are returned.

You will either be allowed to use your own personal cell phone for study communications or receive a prepaid cell phone. If you choose to use a phone we provide, it will be restricted so that you will only be able to communicate with study personnel and 911 service. If you choose to use your personal cell phone for study communications and pay for text messages and/or phone calls on a per unit basis, we will reimburse you for the cost of those messages and calls conducted as part of this study. To protect your privacy, we recommend that a password-protected lock be enabled on the cell phone used for this study and that the device remains locked when not in use.

When you return to VTCRI after the initial 7-day period to receive a SOBERLINK breathalyzer, you will generate or list positive episodic thinking cues at different past or future time points. The intervention period will last for 14 consecutive days, with three breathalyzer screens per day. You will be asked to designate a time at the start of the hour at which each of the three breathalyzer screens will be scheduled each day. You will be asked to choose an assessment time shortly after you usually awaken, shortly before you go to bed at night, and one throughout the day. You will be allowed to choose any times for the screens, provided that they are each separated by at least 6 hours. You will be reminded via text message when a sample is to be collected, and samples will be accepted up to 15 minutes before the scheduled time and 60 minutes after the scheduled time, giving you 75 minutes total to submit the sample. Also, during this 14-day period, as you did during the initial 7-day period, you will also self-report your previous-day alcohol use with a text message and/or phone call.

To complete scheduled breathalyzer samples, you will simply blow into the SOBERLINK device for 4 seconds. During the breath sample collection, a picture is automatically taken of you, which can be compared to a reference picture taken when you first receive the SOBERLINK device. The SOBERLINK device will automatically upload the breathalyzer results, your location, and your picture to a centralized, secure website where the data will be available to research staff. Research staff will monitor these results, verify that the picture matches a reference picture for you, and you will receive compensation based on completed breath samples.

Assessment sessions will be conducted prior to the intervention, immediately following the intervention, and at a 1-month follow-up. During assessment sessions, we will collect some measures of your alcohol and drug use and ask you to complete a number of questionnaires and tasks. We will ask you to complete a battery of questionnaires and tasks grouped into three general categories including measures of your substance use, measures of treatment acceptability, and measures of alcohol value and sensitivity.

Remote delivery of payments

You will be paid with a reloadable prepaid card issued by Greenphire ClinCard (www.myclincard.com), an FDIC-insured payment provider that specializes in clinical trial stipend payments that comply with IRB privacy regulations and considerations. At intake, you will receive a prepaid MasterCard debit card that can be used anywhere that accepts MasterCard. As payments are earned in the course of the study, additional funds will be added to your account. Funds are immediately available when added and you can check your balance as desired.

Risks/Discomforts/Inconvenient

One risk of participating in this study is a possible embarrassment. This may result from answering questions that you consider sensitive. Some of our questions will ask for information about medical and psychiatric conditions and drug use.

Alcohol-dependent adults that reduce drinking might experience mild alcohol withdrawal (e.g., anxiety, agitation, headache, hypertension, insomnia, irritability). Participants who are likely to experience more than mild withdrawal symptoms may be excluded from the study. Neither the researchers, VTCRI, or Virginia Tech have money set aside to cover the cost of any resulting medical treatment, and any costs associated with that treatment would be the responsibility of the participant.

In addition, loss of confidentiality is another potential risk of participation. We will make every effort to protect your confidentiality should you participate in this study. Study data will be secured and breathalyzer transmissions are encrypted and secured. However, there is a potential that data could be intercepted affecting your employability or probation status. To protect against this risk, we recommend that the cell phone used for study communications be locked when not in use. There is also the possibility you may become bored during the research sessions.

If problems occur during the course of the study we will determine whether you should continue. If necessary, referrals will be provided. If you have questions concerning the study, please contact Warren K. Bickel, the Principal Investigator at 540-526-2088 (office).

Possible Benefits

You may benefit from a possible reduction in alcohol use or cessation of alcohol use. The project involves minimal risk to confidentiality or other personal rights or to physical or emotional health.

Voluntary Participation and Confidentiality

Your participation in this study is voluntary. You are free to decline participation in this study or withdraw from it at any time. If you are a Virginia Tech student, you may withdraw from the study

without affecting your academic standing (i.e., your student status and evaluations will not be affected). We will act in accordance with the guidelines for the protection of human research participants issued by the Institutional Review Board (IRB) and Office of Research Compliance (ORC). Your identity on records relevant to this study will not be made public. Any publications resulting from this research will not mention your name or any other personally-identifying information.

It is possible that the Institutional Review Board (IRB) may view this study's collected data for auditing purposes. The IRB is responsible for the oversight of the protection of human subjects involved in the research. The sponsor (VTCRI) or their appointed designees as well as the IRB, ORC, or other institutional oversight offices will be granted direct access to your original research records for verification of data. If your record is used or distributed for government purposes, this will be done under conditions that will protect your privacy. You will be informed of any significant new findings that may relate to your continued participation in this study.

The study team must release certain information to the appropriate authorities if at any time during the study there is a concern that child abuse or elder abuse has possibly occurred or you disclose a desire to harm yourself or others.

Compensation

You will receive $15 compensation for the consent session and $25 for the first assessment session. If eligible to continue, you will receive $30 for completing the second assessment session, $35 for completing the third assessment session, and $40 for the follow up (fourth) assessment session. In addition, you will receive up to $7 compensation for completing the daily self-reports of alcohol use during the initial 7-day period and up to $56 for submitting the breathalyzer samples and reporting previous-day drinking for the 14-day intervention period. You will also receive $50 for returning your SOBERLINK device and prepaid cell phone (if applicable). These payments will be up to $258 per participant but maybe less.

Visit Duration	Approx. 2 hours		Approx.1 hour		Approx. 2 hours	Approx. 2 hours
Study Activities	Consent + Session 1	7-day period	Session 2 (Pre-intervention)	14-day intervention period	Post-intervention Assessment Session 3	1-month follow-up Assessment Session 4
Compensation	$15 (consent) + $25 (assessment)	$1/day	$30	$4/day	$35 + $50 SOBERLINK return completion bonus	$40

If you receive compensation greater than $600.00 for research participation (not limited to this study), the amount received will be reported to the IRS and you will receive an IRS 1099 Form. We will collect social security numbers and retain them for IRS and auditing purposes.

Alternative to Participation

You do not have to participate in this study if you do not wish to. Your employment status, student status, grades, extra-curricular activities, or medical treatment will not be affected in any way. You can

find a list of local AA meetings at http://aaroanoke.org/ and other treatment services in the area at http://local.soberrecovery.com/Alcohol_Rehab_Roanoke_VA-r1298538-Roanoke_VA.html. We are not affiliated with or endorse the services listed in either of these resources.

Subject's Responsibilities

I voluntarily agree to participate in this study. I have the following responsibilities:

- Answer questions about health, and past and current substance and alcohol use
- Provide breath samples to test for recent alcohol use
- Complete laboratory assessments
- Notify the researchers if I experience any discomfort or would like to discontinue participation from this study
- Let the researchers know if I have any comments, questions or concerns regarding participation in this study

Subjects Permission/Statement of Consent

The purpose and voluntary nature of this study, as well as the potential benefits and risks that are involved, have been explained to me. I have read the Consent Form and conditions of the project. I have been able to ask questions and express concerns, which have been satisfactorily responded to by the study team. I have been told that I will be given a copy of this consent form. I hereby acknowledge the above and give my informed and free consent to be a participant in this study. I recognize that I am not waiving any of my rights as a research participant by signing this consent form.

If you have questions about this study, please contact Dr. Warren Bickel, the Principal Investigator at 540-526-2088 (Telephone)/wkbickel@vtc.vt.edu (e-mail). If you have any questions about your rights as a research subject or concerning a research-related injury, you can call the Virginia Tech Institutional Review Board for the Protection of Human Subjects at 540-231-3732 or irb@vt.edu (e-mail).