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Loss Aversion in Cocaine Users: Influence of Risk and Commodity Type

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LOSS AVERSION IN COCAINE USERS: INFLUENCE OF RISK AND COMMODITY TYPE

THESIS

A thesis submitted in partial fulfillment of the
requirements for the degree of Master of Science in the
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By

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Lexington, KY

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ABSTRACT OF THESIS

LOSS AVERSION IN COCAINE USERS: INFLUENCE OF RISK AND COMMODITY TYPE

Numerous studies in behavioral economics have demonstrated that individuals are more sensitive to the prospect of a loss than a gain (i.e., loss aversion). Although loss aversion has been well described in healthy populations, little research exists in individuals with substance use disorders. The purpose of this study was to comprehensively evaluate loss aversion in cocaine users. Participants completed measures designed to assess loss aversion for drug and non-drug commodities under varying risk conditions. Cocaine demand was determined using a cocaine purchase task. Cocaine users showed a loss aversion score that was consistent across commodity and risk conditions. Compared to the normative loss aversion coefficient value (i.e., $\lambda = 2$) a large effect size decrease in loss aversion was observed in cocaine users. Hypothetical demand for cocaine was well explained by demand models. More intense and inelastic cocaine demand was also associated with greater loss aversion for cocaine. These data represent the first systematic study on loss aversion in cocaine using populations and indicate that reduced loss aversion is associated with cocaine use. Future studies should explore potential behavioral and neurobiological mechanisms to determine the benefit of loss aversion for treatment and intervention development efforts.

KEYWORDS: Behavioral Economics; Demand; Drug; Gamble; Prospect Theory

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Chapter 1: Introduction

Substance use disorders present a persistent public health concern, with the annual economic impact of illicit drug use estimated at $193 billion in the United States (United States Department of Justice, 2011). The most recent National Survey on Drug Use and Health (NSDUH) indicates that nearly 1.5 million persons aged 12 or over were current cocaine users and over half of those individuals met diagnostic criteria for a cocaine use disorder (Center for Behavioral Health Statistics, 2015). Other sources indicate that the NSDUH may underestimate the prevalence of active cocaine use, and that as many as 3.9 million individuals use cocaine four or more times per month (Caulkins, Kilmer, Reuter, & Midgette, 2014). Cocaine use poses a particularly salient concern due to the relative lack of effective behavioral and pharmacological treatments for those seeking abstinence. Despite sustained efforts at identifying behavioral interventions and pharmacotherapies for cocaine use disorder, few effective treatments exist, and those that do suffer from selective effects, low retention, and high relapse rates (Dutra et al., 2008; Stoops & Rush, 2013).

Many of the diagnostic criteria for cocaine and other substance use disorders are defined by behaviors relevant to choice and decision-making. In the most recent edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-V) cocaine use disorder is diagnosed based on criteria including: an individual's use of more cocaine than intended; unsuccessful efforts to control cocaine use; spending a large amount of time finding, using, or recovering from the effects of cocaine; using cocaine to the exclusion of other activities; continued use of cocaine despite problems caused by use; and use of cocaine in dangerous situations (American Psychiatric Association, 2013). Understanding how maladaptive patterns of choice develop and persist in substance use disorders is critical to identifying mechanisms of disease etiology and advancing intervention design.

Behavioral economics is the field of economics that characterizes choice and decision-making under conditions of constraint and attempts to explain departures from classic economic theory and decisions based on expected utility. Behavioral economic theorists posit that suboptimal behavior is a consequence of systematic choice biases that depart from traditional economic decisions (i.e., expected utility decisions). The recent application of behavioral economic principles to substance use research has resulted in exciting advances in both theoretical and empirical domains (Chivers & Higgins, 2012). For example, research on delay discounting has improved the field's understanding of the etiology and treatment of substance use disorders. Delay or temporal discounting refers to the systematic reduction in the value of reinforcers as a function of delay to reinforcer delivery (Rachlin & Green, 1972). Numerous studies have demonstrated excessive discounting of delayed reinforcers in substance using populations, and the knowledge of this systematic bias has helped guide recent intervention efforts (e.g., as a putative moderator of treatment efficacy) (Bickel, Jarmolowicz, Mueller, Koffarnus, & Gatchalian, 2012; Washio et al., 2011). Exploration of other, understudied mechanisms of disordered choice could also result in significant research gains.

Loss aversion is a choice bias that has received a great deal of attention in the behavioral economic literature (Novemsky & Kahneman, 2005). Numerous studies have demonstrated that, all things being equal, losses tend to have a greater impact on behavior than gains (Kahneman & Tversky, 1979; Tversky & Kahneman, 1991, 1992). For example, an individual receiving a $20 parking fine will report a greater magnitude impact on behavior than an individual winning a $20 bet. This idea that losses loom larger than gains is used to explain a range of behavioral phenomena, such as the endowment effect (i.e., that individuals will sell a good for on average twice as much as they are willing to pay for the same good) (Rick, 2011). Despite the prevalence of

research exploring loss aversion in traditional economic contexts, little research exists that focuses on clinical populations. Even less attention has been paid to understanding loss aversion in substance using populations. The results of a PubMed search using the keywords “loss aversion” AND “drug” reveals only 17 papers, six of which are literature reviews. Investigating loss aversion in active substance users may provide critical insight into the etiology of substance use disorders and treatments targeting the suboptimal choices characteristic of drug use.

Prospect Theory and Loss Aversion

Prospect theory is a seminal model in behavioral economics used to explain choice in situations of risk, loss, and uncertainty (Kahneman & Tversky, 1979; Tversky & Kahneman, 1992). Central to prospect theory is the notion that behavioral preference is not determined by the final outcome of a choice, but instead, by the change relative to a reference point. In this way, it is not that a bank account might have changed by $50; it is whether this change was a gain or a loss that determines the relative impact. Value, then, is not an objective constant and is influenced by the relative reference point of a decision and its consequence.

A key phenomenon explained by prospect theory is loss aversion. As described above, all things being equal, people are more sensitive to the prospect of losing a commodity than the prospect of gaining an equally valued commodity. Prospect theory predicts that receiving a $500 raise would produce a smaller magnitude positive impact than the negative impact of a $500 pay cut. Whereas when an employee that receives a raise might feel pleased and enthusiastic, if she were to receive a cut in pay, she might be deeply outraged or saddened. Although in both instances the objective value of the change is equal, the reference point differs. Thus, at the broadest level, prospect theory and loss aversion suggest that the framing of an outcome as a loss or gain is a critical determinant of behavior, choice, and affective impact.

Mathematical models and behavioral measures of loss aversion are often used to quantify the relative impact of losses as compared to gains. The ratio comparing the relative value of avoiding losses to the pursuit of gains is described by the loss aversion coefficient, lambda (λ). Numerous studies have demonstrated that in the general population λ is approximately equal to 2 (Novemsky & Kahneman, 2005). This value suggests a 2:1 ratio of loss to gain, or that the impact of a loss is approximately twice that of an equivalent gain. This value also indicates that a gain must be twice the value of a loss to be of equal utility. Returning to the example of the disgruntled employee, only if her raise were $1000 would it be subjectively equal to a $500 cut in pay.

Loss aversion occurs under both conditions of certainty (i.e., riskless) and risk regarding the outcome of that choice. Riskless choice refers to situations of certain outcome, such as buying or selling a commodity for a pre-determined price (Tversky & Kahneman, 1991). Loss aversion in this context is the behavioral mechanism used to explain the endowment effect wherein an individual will request on average twice as much to sell a commodity as he or she is willing to pay for that same good (Novemsky & Kahneman, 2005). For example, an employee may want a chocolate bar and be willing to buy it from a vending machine for $1.00. But if that employee's friend also wanted a chocolate bar and decided to buy it from her, loss aversion and the endowment effect would predict that she would request at least $2.00 to sell her chocolate bar.

Risky choice occurs during decisions of probability or chance (e.g., when making a gamble). Loss aversion in this context denotes disfavor of gambles with possible losses. The commonly confused phenomenon of risk aversion refers to a more general aversion towards outcome variability, regardless of whether that outcome is a loss or a gain. Individuals are more likely to reject gambles of positive expected value if the potential for loss is up to half as much as the expected gain (Tom, Fox, Trepel, & Poldrack, 2007). For example, if the employee decided to make some cash on the side and started

betting on coin flips with her coworkers, it is unlikely that she would accept gamble if the consequence was “heads you win $10 and tails you lose $10.” Even if the payoffs were a $10 gain for heads and a $6 loss for tails, she would still be unlikely to accept the bet. Only when the possible gain was twice or more the possible loss would she likely accept (e.g., $10 win to $5 loss).

Although choice under certainty and under risk may present as qualitatively different conditions, the quantitative expression of loss aversion is similar. Both risky and riskless conditions produce loss aversion and result in loss aversion coefficients of approximately 2 (Novemsky & Kahneman, 2005; Tom et al., 2007). The similarity in these experimental outcomes is suggestive of a common behavioral mechanism underlying choice. However, few studies have examined the relationship among behavioral measures of loss aversion using within-subjects manipulations. Those studies that do exist suggest that loss aversion is consistent across conditions of certainty and risk (Gachter, Johnson, & Herrmann, 2007). Additional research that directly compares behavioral measures of loss aversion under certainty and risk is needed.

Measures of Loss Aversion

Loss aversion has received a great deal of attention in the behavioral economic literature, with numerous studies demonstrating a robust and reliable avoidance of losses relative to pursuit of gains under certain and risky conditions. A number of behavioral tasks have been developed that quantitatively measure loss aversion. Many of these tasks define loss aversion by using a standardized loss aversion coefficient (i.e., λ) allowing for comparisons across studies and populations.

One of the most popular tasks used to examine loss aversion is the valuation task (Kahneman, Knetsch, & Thaler, 1990). The valuation task is a measure of loss aversion under certain conditions. In the original version of this task, participants were randomly divided into a “buy” or “sell” group. Participants in the “buy” group were shown a

commodity (i.e., a coffee mug) and asked the maximum amount of money they were willing to spend to buy the mug. Participants in the "sell" group were given the same commodity and asked the minimum amount of money they were willing to sell the mug for. The ratio of sell to buy (or "Willingness-to-Accept to Wiliness-to-Purchase"; WTA:WTP) provides a behavioral index of loss aversion.

In one of the earliest studies, students from a business statistics class were randomly selected to be buyers or sellers of a coffee mug (Kahneman et al., 1990). Participants were allowed to choose to buy (or sell) at prices ranging from $0.00 to $9.50 in $0.50 intervals. Sellers in that study requested nearly double the median price compared to buyers, concordant with predictions from prospect theory (medians = $5.75 to $2.21; $\lambda = 2.6$). Since then, numerous studies have replicated this finding across commodities (e.g., pens, orange juice, etc.) and shown sensitivity to experimental manipulations such as time (e.g., length of ownership) and likelihood of trading the commodity in the future (see reviews by Morewedge & Giblin 2015; Novemsky & Kahneman, 2005). For example, a short expected length of ownership attenuates the WTA to WTP gap, whereas decreasing the opportunity to trade or sell the good at a later date enhances this gap.

More varied behavioral measures of loss aversion exist for conditions of risky choice. One popular method for examining deficits in decision-making is the Iowa Gambling Task (IGT; Bechara, Damasio, Damasio, & Anderson, 1994; Bechara et al., 2001). In the IGT, participants make a series of choices from four decks of cards in which every choice results in a gain that is sometimes coupled with a simultaneous loss. Selections from two disadvantageous decks results in a net loss, whereas selections from two advantageous decks results in a net gain. In the original demonstrations of the IGT, participants with ventromedial prefrontal cortex damage showed poor performance attributed to an indifference for long-term consequences (Bechara, Damasio, Tranel, &

Damasio, 1997). A number of investigators have used the IGT in the context of loss aversion and attributed poor performance to deficits in the anticipation of long-term consequences for disadvantageous decks, hypersensitivity to rewards, and/or hyposensitivity to losses (e.g., Ahn et al., 2014).

A distinct limitation of the IGT is the difficulty in distinguishing the relative contribution of loss aversion from the inability to learn from feedback. One solution is the use of mathematical modeling to decompose IGT behavioral performance into distinct behavioral constructs. For example, the Prospect Valence Learning (PVL) model divides performance into four constructs: 1) loss aversion (λ), 2) reward sensitivity (α), 3) recency (A), and 4) consistency (c) (Ahn, Busemeyer, Wagenmakers, & Stout, 2008; Fridberg et al., 2010; Vassileva et al., 2013). Alternatively, the Expectancy Valence (EVL) model divides performance into three constructs: 1) motivation (responsiveness to risk), 2) learning/memory (updating expectancies about the value of risky alternatives), and 3) sensitivity/consistency (trial-by-trial matching with expected outcomes) (Busemeyer & Stout, 2002; Lane, Yechiam, & Busemeyer, 2006; Stout, Busemeyer, Lin, Grant, & Bonson, 2004). The use of mathematical modeling has provided evidence of differential loss aversion in various clinical populations (Ahn et al., 2014; Busemeyer & Stout, 2002; Fridberg et al., 2010; see below for more detail).

A popular alternative to the IGT, particularly in the economic literature, is the mixed gambles task. Participants in this task are asked to accept or reject gambles of varying probabilities and varying loss-to-gain magnitudes. Although variations in the task may alter the specific probabilities, magnitudes, and choice types (e.g., Gamble #1 versus Gamble #2, Gamble versus No Gamble), these measures have consistently demonstrated loss aversion in the general population. In one of the most popular versions of the mixed gambles task, participants decide whether to accept or reject 50/50 bets (i.e., coin flips) with varying magnitude gains and losses (Tom et al., 2007).

Individuals on this task are more likely to reject gambles in which the possible gain is less than double the possible loss, which is consistent with other measures of loss aversion. For example, a wager with a possible gain of $50 is typically rejected if the possible loss is $25 or more. A major benefit of the mixed gambles task is that skill and prior learning do not mediate performance, unlike the IGT. Because gamble results are not displayed throughout the task (i.e., the participant is blind to gamble outcomes), feedback-based responding also does not influence behavior.

Loss Aversion in Clinical Populations

Few studies have examined loss aversion in clinical populations and even fewer have examined individuals with substance use disorders. Attenuated loss aversion has been observed in individuals with schizophrenia under both riskless and risky conditions (Brown et al., 2013; Tremeau et al., 2008). Patients with schizophrenia in one of these studies failed to show loss aversion in a valuation task and demonstrated higher requested prices as buyers than as sellers ($\lambda = 0.87$; Tremeau et al., 2008). Loss aversion coefficients in that study correlated with duration of illness, but not measures of current psychopathology. This finding suggests that altered loss aversion may be a consequence of sustained behavioral and/or biological changes over disease course rather than a function of acute symptomology. Similarly, under conditions of risk, individuals with schizophrenia show deviations from normal decision-making and an impaired assessment of expected value (Brown et al. 2013). In contrast to these findings, patients with depression show enhanced loss aversion relative to control groups (Chandrasekhar Pammi et al. 2015). Performance on a mixed gambles task in that study indicated higher loss aversion coefficients in depressed patients. Furthermore, activity in regions of the midbrain and ventral tegmental area were associated with these enhanced λ values. These findings are notable given that a previous neuroimaging study

in healthy controls also implicated regions of the mesolimbic and mesocortical dopamine systems in loss aversion (Tom et al., 2007).

A series of studies has examined loss aversion in problem gamblers and revealed mixed findings. One of these studies found attenuated loss aversion in gamblers in outpatient treatment that performed the IGT and a mixed gambles task (Lorains et al. 2014). In contrast, another study found that problem gamblers undergoing treatment showed enhanced loss aversion that corresponded with the stage of treatment (i.e., higher loss aversion in later-stage treatment; Giorgetta et al. 2014). In another study, poorer performance on a mixed gambles task and the IGT was observed in non-treatment seeking gamblers (Brevers et al. 2012). Although that study did not directly compute a loss aversion coefficient, performance was consistent with attenuated loss aversion. Taken together, these findings support the notion that loss aversion may relate to and be altered by treatment status in problem gamblers.

Loss Aversion in Substance Using Populations

Little research has evaluated loss aversion in substance using populations and the research that exists has focused on risky loss aversion. A majority of these studies have used the IGT in combination with various computational models in order to isolate behavioral constructs of loss aversion. Few studies exist in substance using populations utilizing mixed gambles tasks, and none have compared loss aversion under certainty and risk by using a within-subjects design.

The acute effects of drugs on loss aversion have been examined in two studies (George, Rogers, & Duka, 2005; Lane et al., 2006). In the first of these studies, participants were administered alcohol (0.6 g/kg) or placebo and asked to perform a mixed gambles task (George et al., 2005). Gambles in this task varied in loss and gain magnitude as well as in probability. Acute alcohol produced an impaired assessment of

gain magnitude and probability. Importantly, no differences in reaction time were observed suggesting that these effects were not due to general motor impairment.

The second of these studies was a retrospective analysis of data from studies evaluating the acute effects of alcohol, cannabis, and alprazolam (Lane et al., 2006). All included studies used an experimenter-designed risk-taking task in which participants chose between a non-risky, low payoff and risky, high payoff option. These data were examined using the EVL model providing measures of reward responsiveness, learning, and outcomes sensitivity. Acute alcohol (0.8 g/kg) produced a heightened sensitivity to rewards and/or decreased sensitivity to losses, but did not change learning from previous outcomes and response sensitivity. In contrast, acute cannabis (3.58%) impaired learning and sensitivity to outcomes, but produced no changes in valence sensitivity. Finally, alprazolam (2 mg) administration only impaired learning from previous outcomes and did not affect valence or response sensitivity. Important to note is that these acute drug effect studies were conducted in social drinkers and student populations. It remains unknown if the reported acute effects of drugs on loss aversion would extend to individuals with substance use disorders.

One study examined abstinent amphetamine- and heroin-dependent individuals performing the IGT whose performance was analyzed using a variety of computational models (Ahn et al., 2014). These participants were in extended abstinence, with at least a three-month period since the last reported drug use. Abstinent heroin users in that study showed attenuated loss aversion relative to healthy controls. Amphetamine-dependent individuals, in contrast, showed increased reward sensitivity, but not attenuated loss aversion relative to controls. These findings indicate that particular decision-making deficits may remain during abstinence, and that these deficits may differ as a function of abused substance.

One study has examined loss aversion in chronic cannabis users (Fridberg et al., 2010). These investigators found that the PVL model provided the best fit to the experimental outcomes and that attenuated loss aversion on the IGT was observed in cannabis users relative to matched controls. These findings indicated that cannabis users treated loss as constant and of relatively minor impact regardless of loss magnitude. Additionally, decisions made by cannabis users showed inconsistency with respect to expected outcomes suggesting an impaired computation of expected value.

A number of studies have demonstrated impaired performance by active cocaine users on the IGT (e.g., Balconi, Finocchiaro, & Campanella, 2014; Hulka et al., 2014; Stout et al., 2004). In one such study, male cocaine users completed the IGT and parameters from computational models were compared to matched controls (Stout et al., 2004). These individuals showed an impaired risk responsiveness resulting in attenuated sensitivity to losses and/or an enhanced sensitivity to gains. Furthermore, cocaine users showed impaired sensitivity to expected value and greater randomness in choice (i.e., non-concordant with expected value). Although no direct measures of loss aversion were computed, these findings are suggestive of an attenuation of loss aversion in cocaine-using populations.

Another study examined women enrolled in a longitudinal study on HIV (Vassileva et al., 2013). A subset of these women reported a history of illicit drug use, including heroin and/or cocaine use. In that study, participants completed the IGT and parameter values were compared using the PVL computational model. Drug use was associated with decreases in loss aversion and impaired learning from feedback and HIV+ status with reductions in loss aversion. However, only 14% of the women in the drug-use condition reported current cocaine use, making inferences about the specific role of active cocaine use on loss aversion difficult.

In contrast to these other studies, data obtained in HIV-positive cocaine users suggests enhanced loss aversion (Meade, Young, Mullette-Gillman, Huettel, & Towe, 2014). Participants in that study performed a mixed gambles task and completed measures of substance use and sexual risk taking. Individuals with active cocaine use reported greater loss aversion than those that did not, and within this group, loss aversion was positively associated with sexual risk behavior and missing medication appointments. It is important to note that these data were presented at the 2014 annual meeting of the College on Problems of Drug Dependence and have not been published in a peer-reviewed format. It is also unclear if these results are a function of cocaine use, HIV status, or a unique combination of the two. Investigating the specific role of active cocaine use in expression of loss aversion will be crucial for clarifying these discrepancies.

The reviewed literature suggests that drug use is related to deviations in expected value computation and loss aversion. These collective findings indicate that the use of drugs from multiple classes, including cannabis, opioids, and psychomotor stimulants, is associated with decreases in loss aversion. Additional research is needed, however, to clarify discrepancies observed in some studies (e.g., Meade et al. 2014) and to understand the cross-context consistency of loss aversion through the use of multi-method, within-subjects techniques.

Implications of Loss Aversion for Substance Use Disorders

Loss aversion could play a role in the etiology and persistence of substance use behaviors. Maladaptive patterns of drug taking maintained by the inability to adequately assess losses and gains and a consequent over- or undervaluation of negative consequences (e.g., withdrawal, unemployment) would likely result in the enduring drug use phenotypes often observed in the clinical setting. Loss aversion may also relate to clinical status as observed in problem gamblers. If this is true, loss aversion could

provide a behavioral marker for substance use diagnosis and assessment. Demonstrating that loss aversion correlates with the clinical expression of cocaine use would be essential for demonstrating a causal role in the clinical condition, rather than as an epiphenomenon of the disorder.

Examining loss aversion in substance using populations may also be important for intervention design. In particular, loss aversion has a substantive relationship to outcomes in contingency management (CM). Differences in loss aversion could potentially affect the subjective impact of monetary incentives when framed as gains as opposed to losses (e.g., "contract-base" CM). Evidence from smoking CM interventions suggests that loss-framed incentives differentially motivate abstinence initiation, whereas gain-framed incentives help to sustain abstinence (Romanowich & Lamb, 2013). Assessing sensitivity to loss aversion could provide a putative moderator of CM efficacy and contribute to patient-level tailoring of CM design.

It is unknown how loss aversion might relate to drug-taking behaviors. The recent development of self-reported purchase tasks to measure economic demand for drugs and other commodities provides a simple method to measure this relationship (e.g., Amlung, McCarty, Morris, Tsai, & McCarthy, 2015; MacKillop et al., 2008; Murphy & MacKillop, 2006). Participants are asked on these tasks to report consumption of specific commodities (e.g., cocaine) across changes in price. Transformation of the price-level consumption into demand curves allows for the mathematical modeling of demand parameters, such as intensity (Q_0; consumption at zero cost) and elasticity (α; a measure of the change in consumption with change in unit price). Additional parameters may also be generated from the raw demand curve (e.g., breakpoint or the point where consumption drops to zero). Demand curves, then, provide the benefit over traditional measures of drug reinforcement (e.g., response rate) of effectively and efficiently isolating several behavioral mechanisms of drug use.

A majority of research on drug purchase tasks has examined alcohol and nicotine consumption (e.g., Murphy, MacKillop, Skidmore, & Pederson, 2009; MacKillop et al., 2008, 2012). Our laboratory has recently developed a cocaine purchase task modified from previous literature (Bruner & Johnson, 2014) and demonstrated reliable outcomes and correspondence between cocaine demand parameters and cocaine use variables (Stoops et al., 2016; Strickland, Lile, Rush, and Stoops, in press; Strickland, Reynolds, & Stoops, in press). The use of a cocaine purchase task in conjunction with measures of loss aversion will allow for the rapid and efficient study of the relationship between these behavioral economic outcomes.

Summary and Purpose

Loss aversion refers to the general tendency for losses to have a greater impact on behavior than equal magnitude gains. Behavioral economics suggests a number of contexts in which loss aversion is expressed, including under conditions of certainty and risk regarding the outcome of choice. Far less is known about loss aversion in substance using populations. The available literature suggests that clinically relevant drug use is associated with diminished loss aversion relative to normative populations. More information is necessary to clarify discrepant results, evaluate the relationship between loss aversion and behavioral mechanisms of drug use, and examine the cross-context consistency of loss aversion through the use of multi-method, within-subjects techniques.

The primary purpose of this study was to examine loss aversion in active cocaine users. Loss aversion was evaluated using a multi-method test battery that varied in the level of risk present and the commodity available. Loss aversion under riskless contexts was assessed using a valuation task and loss aversion under risky contexts assessed using a mixed gambles task. Although previous research supports a correspondence between loss aversion under certainty and risk (Gachter et al., 2007), it

is unknown if this relationship holds in drug-using populations. The commodity available was manipulated in order to evaluate potential differences in loss aversion for drug (i.e., cocaine) and non-drug (e.g., money) outcomes. A risk aversion task was also included to determine the specific contribution of loss aversion over more general aversion to uncertain outcomes.

It was hypothesized that loss aversion would deviate from normative values (i.e., $\lambda = \sim 2$) in active cocaine users. Given the discrepancies reported in prior research, no directional hypothesis was made about this deviation. It was also expected that risky and riskless loss aversion would correlate in active cocaine users, concordant with the relationship observed in the general population. Finally, loss aversion was predicted to be greater for drug than for non-drug commodities.

A secondary aim was to evaluate the relationship between loss aversion and behavioral mechanisms of drug use. A cocaine purchase task was used to isolate behavioral mechanisms of cocaine demand and determine the association between loss aversion and cocaine demand. Additional analyses were conducted to identify individual differences in loss aversion as a function of other cocaine use variables (e.g., monthly cocaine use) and demographics (e.g., age, sex).

Cocaine demand was predicted to decrease as a function of price and be well explained by the exponentiated demand equation. It was also expected that intensity of demand would positively and elasticity of demand negatively correlate with cocaine use variables (e.g., frequency of current cocaine use, lifetime cocaine use), further validating the cocaine purchase task. Loss aversion coefficients were anticipated to correlate with intensity of demand and elasticity of demand, although a directional hypothesis was not made for reasons stated above.

Chapter 2: Methods

Participants

A total of 38 participants (22 male; 16 female) provided sober, written informed consent to participate in this within-subjects, outpatient study. All potential participants underwent a comprehensive screening process (Stoops, Lile, & Rush, 2010). The screening procedure included series of health, psychiatric, and drug use history questionnaires including: the Beck Depression Inventory, Brief Symptom Index, and assessments for ADHD, mental status, and drug and alcohol use disorders. Drug use histories (e.g., time since first use, frequency and quantity of current use, and times used over lifetime) were collected for amphetamines, barbiturates, benzodiazepines, cannabis, cocaine, hallucinogens, inhalants, and opioids. Standardized drug use questionnaires included the Drug Abuse Screening Test (DAST), Fagerström Test for Nicotine Dependence (FTND), and the Michigan Alcohol Screening Test (MAST). Participants also completed the impulsivity subscale of the Zuckerman-Kuhlman Personality Questionnaire (ZKPQ). Diagnostic criteria for Cocaine Abuse or Dependence were assessed using the computerized Structured Clinical Interview for DSM-IV (SCID), but presence of a cocaine use disorder was not an inclusion criterion to allow cocaine use behaviors to freely vary. Participants were excluded if they endorsed a history of serious physical disease, current centrally acting medication, or current or past histories of serious psychiatric disorder that would interfere with study participation. Participants with a history of a substance use disorder that was deemed to interfere with study completion (e.g., physiologic alcohol dependence) were also excluded.

Participants were English-speaking, English-reading, and 18 years of age or older. The sample was generally male (58%) and African American (82%) with a high school or certification-equivalent education (e.g., GED). All participants reported recent cocaine use verified by a cocaine- or benzoylecgonine-positive urine sample. Most participants

reported an extensive history of cocaine use (interquartile range [IQR] = 16 to 26 years) and a majority met criteria for a cocaine use disorder (94.7%). Demographic and self-reported drug use variables are presented in Table 2.1.

Participants were told that the purpose of the study was to learn about how people make decisions. Other than this general explanation of purpose, participants were not given any information concerning what outcomes might be expected. The study was conducted in accordance with all relevant guidelines, including the Declaration of Helsinki, and approved by the Medical Institutional Review Board of the University of Kentucky.

General Procedure

This within-subjects, outpatient study consisted of one session and took approximately one to two hours for each participant to complete. The session took place during screening for other outpatient and inpatient protocols at the University of Kentucky Laboratory of Human Behavioral Pharmacology (LHBP). Participants that met the eligibility criteria above came to the LHBP, underwent a field sobriety test, and provided an expired air sample that was required to be negative for alcohol. Participants were also required to provide a urine specimen that was tested for recent use of amphetamine, benzodiazepines, barbiturates, cocaine, tetrahydrocannabinol (THC), and opioids. This specimen had to be negative for all substances except cocaine to participate in the experimental protocol that day. Sessions could proceed with a THC positive specimen, but the participant had to pass a standard field sobriety test to ensure they were not acutely intoxicated.

Payment Schedule

Participants were provided $30 for use in behavioral tasks and told that they could use this money for purchasing items and making gambles. They were also told that their compensation would vary depending on task performance, but that the total amount

earned would not be less than $0 (i.e., they would not owe the experimenters money). In actuality, all participants earned $10 for the mixed gambles and risk aversion tasks (see below) for a maximum compensation of $60 dependent on valuation task choice (valuation task commodities received + $20 to $60 task compensation).

Behavioral Measures and Task Analyses

Valuation Task: Loss Aversion Under Certainty. A valuation task was used to determine loss aversion under certainty (Gachter et al., 2007; Kahneman et al., 1990). In the "Willingness-to-Accept" (WTA) condition, participants were given a commodity (e.g., coffee mug) and told they could keep it. Participants were then asked to indicate the price(s) at which they would be willing to sell the commodity. Prices varied from $0.50 to $10.00 in $0.50 increments for non-drug commodities. The "Willingness-to-Purchase" (WTP) condition was identical except that participants were shown the commodity and told they had the opportunity to purchase it. Participants were then asked to indicate at each price whether they were prepared to buy the commodity. Although valuation tasks have typically used a coffee mug as the commodity, the current study also used headphones given that pilot testing indicated that participants considered headphones an ecological relevant commodity. Participants were told that one price point from the task would be randomly selected and the decision carried out (e.g., receipt of the good or money) to encourage active participation. A novel cocaine valuation task was also used to assess loss aversion for drug commodities. Participants were asked to make hypothetical decisions about purchasing or selling 1 g of cocaine for prices ranging from $10 to $200 in $10 increments. All other procedures were identical to the traditional valuation task.

Headphone, mug, and cocaine valuation tasks were presented in a randomized order. Presentation order for the WTA and WTP conditions was also counterbalanced across participants with approximately 30 minutes between tasks to avoid carryover

effects. The primary outcome from the valuation task was the ratio of WTA/WTP that provides a standardized measure of loss aversion (i.e., λ). Previous research indicates normative values for λ of approximately 2, indicating that individuals will typically ask for twice the amount to sell than they will to purchase the same commodity (Kahneman et al., 1990; Novemsky & Kahneman, 2005).

Mixed Gambles Task: Loss Aversion Under Risk. A mixed gambles task (i.e., coin flip task) was used to determine loss aversion under risk (Tom et al., 2007). Participants were asked to accept or reject gambles offering a 50/50 chance of winning or losing variable amounts of money. Gains ranged from $10 to $40 in increments of $2, whereas losses ranged from $5 to $20 in increments of $1. These ranges were selected to produce a range of gambles that could account for an approximate two-fold difference in sensitivity to loss versus gain (λ = 2) and to be consistent with previous uses of the task. All 256 possible combinations of gains and losses were presented in a randomized order. Participants were told to respond carefully because one trial would be chosen at random and compensation provided based on that trial. However, as indicated above, all participants were paid $10 for participation in the mixed gamble and risk aversion tasks. The primary outcome from this task was λ, calculated as $\lambda = -\beta_{loss}/\beta_{gain}$ derived from the logistic regression of 1) gain magnitude and 2) loss magnitude on trial choice (i.e., accept versus reject as the criterion). Participants were excluded if the logistic regression model could not converge or when the validity of the model fit was in question (e.g., complete or quasi-complete separation). Nine participants were excluded from one or more mixed gambles analyses because their choices did not allow for generation of accurate λ terms using logistic regression (Money Task Only = 2; Cocaine Task Only = 4; Both Tasks = 3). In general, this reflected a propensity to accept too many gambles (e.g., all gambles), such that generation of logistic regression coefficient terms was not accurate.

Risk Aversion Task. A risk aversion task was used to assess general aversion towards outcome variability (De Martino, Camerer, & Adolphs, 2010). Participants were presented with double or nothing gambles. The task consisted of 11 trials and included the following monetary values: $2, 5, 10, 15, 20, 25, 30, 35, 40, 45, and 50. Participants were told to respond carefully because one trial would be chosen at random and compensation provided based on that trial. However, as indicated above, all participants were paid $10 for participation in the mixed gamble and risk aversion tasks. The primary outcome from the risk aversion task was the number of gambles accepted. Previous studies of loss aversion have used this measure to account for general distaste for risk over a specific aversion to loss (De Martino et al., 2010).

Cocaine Purchase Task. A cocaine purchase task was used to assess economic demand for cocaine (Stoops et al., 2016). Participants were asked to indicate the hypothetical number of cocaine "hits" (i.e., 0.1 g cocaine units) they would purchase at 16 monetary increments ranging from $0.00 [free] to $1000 per 0.1 g. All choices were hypothetical and were not purchased or administered. Data from the cocaine purchase task were analyzed using nonlinear regression and the exponentiated demand equation (Koffarnus, Franck, Stein, & Bickel, 2015; Strickland et al., in press; Equation 1):

$$\text{Equation 1: } Q = Q_0 * 10^{k*(e^{(-\alpha*Q_0*C)}-1)}$$

Where Q = consumption; Q_0 = derived intensity of demand (consumption at zero price); k = a constant that denotes the range of consumption values in $\log_{10}$ units (set to 4 for all analyses); C = the price of the commodity; and α = derived essential value (a measure of elasticity of demand). Greater values of Q_0 indicate greater consumption at unconstrained price (i.e., a theoretical price of zero). Greater values of α indicate a higher elasticity of demand or change in consumption with change in unit price.

Purchase task data have traditionally been modeled using the exponential demand equation (Hursh & Silberburg, 2008; Equation 2):

Equation 2: $\log_{10} Q = \log_{10} Q_0 + k * (e^{(-\alpha * Q_0 * C)} - 1)$

However, recent evidence indicates that the exponentiated model provides a superior fit because this model can incorporate zero consumption values without transformation (Koffarnus et al., 2015; Strickland et al., in press). Given the relative novelty of the exponentiated model, the exponential model was tested to verify the exponentiated model's superior fit. Zeros were replaced with an arbitrary non-zero number (0.01) for the exponentiated model analysis, consistent with standard practice (Koffarnus et al., 2015). Table 2.2 presents the timeline for all experimental tasks and procedures.

Data Analysis

Primary Outcomes: Loss Aversion as a Function of Risk and Commodity. Standardized loss aversion coefficients (λ) were calculated for individual tasks as described above. One-sample *t*-tests were used to determine if λ values differed from the population normative value of 2. This value was selected because it is the typical λ value observed in non-clinical (i.e., normative) populations (see Kahneman & Tversky, 1979; Novemsky & Kahneman, 2005; Tversky & Kahneman, 1992). This value also lies within the range of values described by several meta-analyses on WTP/WTA disparities (Neumann & Böckenholt, 2014; Sayman & Öncüler, 2005; Tunçel & Hammitt, 2014). Loss aversion 95% confidence intervals were evaluated to determine the precision of the present estimate and the margin of difference from the prototypic value of 2.

A follow-up analysis was conducted with valuation task data to determine if the within-subjects manipulation presented a potential confound (e.g., carryover responding from WTP to WTA or vice versa). This analysis closely resembles the methods used in traditional valuation task studies in which each participant only completes one task (i.e., a between-subject manipulation). Data from the first task each participant completed

were used and independent-samples *t*-tests conducted comparing WTA and WTP values between groups. Median values for WTP and WTA were also used in this follow-up analysis to generate estimated λ values. Median values were used in this between-subjects designs to account for potential distributional skew and/or outliers as described previously (see Kahneman et al., 1990). A secondary analysis of mixed gambles data was also conducted to determine the predicted probability of gamble acceptance at an expected value of zero, as well as the expected value at which the predicted probability of gamble acceptance was 50%. These values were determined using logistic regression with expected value as the predictor and choice as the criterion.

A high proportion of participants (60.5%) indicated that the price range used for the headphone valuation task was too restrictive and that they would sell or purchase the headphones for more than $10.00. Given this potential methodological confound, only the mug commodity was used for the remainder of analyses. The influence of risk and commodity type on loss aversion was examined using a 2 x 2 ANOVA with Risk (Riskless versus Risky) and Commodity (Non-Drug versus Drug) as the within-subjects factors. Risk aversion and counterbalance order were included as covariates in additional models to evaluate the influence of these potential confounds on study outcomes. The effects of Risk and Commodity Type were also evaluated using linear mixed-effects models in the lme4 package for R statistical software (Bates, Maechler, Bolker, & Walker, 2015), with Risk, Commodity, and the Risk x Commodity interaction defined as fixed, within-subjects factors and participant defined as a random factor. An alternative approach of using difference scores (e.g., WTP – WTA) rather than ratios was also explored. The outcomes of these analyses were not qualitatively different than ratios, and therefore, for parsimony and comparison to the broader research literature, only ratio analyses are reported. The relationship between λ values from valuation and mixed-gambles tasks were analyzed using Spearman rank correlations. Non-parametric

Spearman rank correlations were used for to help control type I and type II error rate inflation due to non-normal variable distributions (Bishara & Hittner, 2012).

Secondary Outcomes: Individual Differences in Loss Aversion. Cocaine purchase data were analyzed in GraphPad Prism 6.0f (GraphPad Software Inc.; La Jolla, CA), as described above. Additional parameters, including intensity (consumption at zero price), O_{max} (maximum amount of money allocated to cocaine purchase), P_{max} (price at which O_{max} is achieved), and Breakpoint (first price at which consumption is zero) were computed graphically (e.g., Amlung et al., 2015; MacKillop et al., 2008; Murphy & MacKillop, 2006). All demand metrics were log-transformed to correct for a high degree of skew. The relationship between derived intensity (Q_0) and reported consumption at zero price was used to evaluate model appropriateness. Multiple regression models including gain and loss coefficients (e.g., WTP, WTA) and λ values were used to evaluate the relationship between λ and purchase task and demographic outcomes. The incremental validity of adding λ to models including components of the ratio was determined and statistically significant increments in R^2 interpreted using semi-partial correlations. Spearman rank correlations were also used to determine if purchase task metrics were associated with other drug use (e.g., DAST, monthly cocaine use) and demographic (e.g., age, sex) variables. All ANOVAs and correlational analyses were conducted in SPSS Statistics 22 (IBM; Armonk, NY) with a type I error rate of 0.05.

Power Analysis

An *a priori* power analysis was conducted to determine the sample size needed to detect a medium effect size difference from 2 for λ (Cohen's d = .50) using two-tailed tests and a type I error rate of .05. This power analysis indicated that 38 participants would be needed to detect this effect with 85% power.

Table 2.1 Participant Demographics and Drug Use Variables

	Mean	SD
Age	45.7	5.8
Females	16 (42%)	
Race		
Caucasian	7 (18%)	
African American	31 (82%)	
Years of Education	12.1	1.5
Income	$7155	$7479
ZKPQ	1.4	1.7
CPD	11.8	7.4
FTND	3.8	2.3
Alcoholic Drinks Per Week	14.6	17.0
MAST	8.4	8.8
DAST	10.2	5.6
Cocaine Use		
Days Used Per Month	15.7	9.2
Money Spent Per Month	$659.5	$701.0
Lifetime Uses	3562.6	2715.6
Years Used	20.3	8.3

Note. ZKPQ = Impulsivity Subscale of the Zuckerman-Kuhlman Personality Questionnaire; CPD = cigarettes per day; FTND = Fagerström Test for Nicotine Dependence; MAST = Michigan Alcohol Screening Test; DAST = Drug Abuse Screening Test.

Table 2.2 Timeline for Experimental Procedures

Time	Experimental Activity
0 h	Arrival
0 – 0.25 h	Sobriety Test, Urine Screen, Pre-Session Paperwork/Informed Consent
0.25 – 0.50 h	Traditional and Cocaine Valuation Tasks 1 (WTA/WTP)*
0.50 – 0.75 h	Traditional Mixed Gambles Task
0.75 – 1.00 h	Break
1.00 – 1.25 h	Cocaine Mixed Gambles Task
1.25 – 1.50 h	Traditional and Cocaine Valuation Tasks 2 (WTA/WTP)* Risk Aversion and Cocaine Purchase Task
1.50 h	Participant Payment/Discharge

*Presentation of Willingness-to-Accept (WTA)/Willingness-to-Purchase (WTP) conditions of valuation tasks counterbalanced across participants

Chapter 3: Results

Valuation Task Performance

Means and standard deviations for WTP, WTA, and λ values on the headphone, mug, and cocaine valuation tasks are presented in Table 3.1. Similar magnitude prices for selling (WTA) and buying (WTP) conditions were observed for all commodities, as indicated by an average λ of approximately 1 (Headphones = 1.04; Mug = 1.15; Cocaine = 1.14). One-sample *t*-tests showed that λ values for all commodities were significantly lower than a standard value of 2, t_{37} values > 6.95, *p* values < .001, *d* values > 1.13 (see Table 3.1).

Follow-up analysis analogous to the methods used in traditional valuation task studies (i.e., using only data from the first task completed by each participant) supported the conclusions from the within-subjects comparisons. Specifically, independent-samples *t*-tests did not reveal statistically significant differences in prices for selling and buying conditions for the three commodities, Headphones: t_{36} = 0.77, *p* = .45; Mug: t_{36} = 0.69, *p* = .49; Cocaine: t_{36} = 0.61, *p* = .55. Similar magnitude λ scores as the within-subjects data were also observed when using WTA and WTP values from this first task only subset (λ: Headphones = 0.83; Mug = 1.20; Cocaine = 1.17).

Mixed Gambles Task Performance

Means and standard deviations for λ on the mixed gambles task as well as gain and loss coefficients are presented in Table 3.2. Participants were, on average, equally sensitive to the magnitude of loss and gain as reflected by mean λ values of approximately 1 (Money Task = 0.99; Cocaine Task = 1.08). One-sample *t*-tests supported this conclusion by indicating a statistically significant difference from a λ of 2 for money, t_{32} = 8.82, *p* < .001, *d* = 1.53, and cocaine, t_{30} = 8.63, *p* < .001, *d* = 1.55.

Excluded participants reported more frequent cocaine use (22 versus 14 average days per month, t_{36} = 2.38, *p* = .02) and higher nicotine dependence scores (5.3 versus

3.4 average FTND, $t_{36} = 2.47$, $p = .02$), but did not differ on other demographic and drug use variables. Additionally, included and excluded participants did not differ on loss aversion values generated from the valuation tasks, Headphones: $t_{36} = 0.29$, $p = .77$; Mug: $t_{36} = 0.42$, $p = .68$; Cocaine: $t_{36} = 0.09$, $p = .93$.

A secondary analysis of mixed gambles data indicated that the average predicted probability of gamble acceptance at an expected value of zero was 38.9% for cocaine and 30.8% for money. The expected value at which the predicted probability of gamble acceptance was 50% for the monetary and cocaine mixed gambles task was, on average, $3.5 and 0.0 grams cocaine, respectively.

Loss Aversion by Risk and Commodity Condition

Figure 3.1 displays λ values as a function of risk and commodity type. All 95% confidence intervals did not overlap with the normative value of 2 and indicated estimate precision as evidenced by tight interval width. A 2 x 2 ANOVA did not reveal a statistically significant main effect of Risk, $F_{1,28} = 1.66$, $p = .21$, $\eta_p^2 = .06$, main effect of Commodity, $F_{1,28} = 0.05$, $p = .83$, $\eta_p^2 < .01$, or Risk x Commodity interaction, $F_{1,28} = 0.64$, $p = .43$, $\eta_p^2 = .02$. Counterbalance order and risk aversion did not impact these relationships as indicated by the lack of statistically significant main effects or interactions when included in the model. Similar results were observed when using linear mixed-effects models, with no statistically significant effects of Risk, $p = .29$, Commodity, $p = .95$, or Risk x Commodity interaction, $p = .63$. Loss aversion coefficients were also not significantly correlated with risk aversion, Mug Valuation: $r_{sp} < .01$, $p = .98$; Cocaine Valuation: $r_{sp} = .14$, $p = .41$; Traditional Gambles: $r_{sp} = .08$, $p = .65$; Cocaine Gambles: $r_{sp} = .19$, $p = .28$.

Figure 3.2 contains individual participant data from the valuation task (circles) and mixed gambles task (squares). Individual data matched the group-averaged analyses well. Tight clustering was observed around mean values with few values deviating from

this central tendency (SDs: Non-Drug Valuation = 0.75; Drug Valuation = 0.58; Non-Drug Mixed Gambles = 0.66; Drug Mixed Gambles = 0.59). Furthermore, few participants exhibited loss aversion scores greater than 2 (~2-3 participants per task).

Spearman correlations among loss aversion coefficients revealed two statistically significant associations. Higher loss aversion values on the mug valuation task were associated with higher values on the cocaine valuation task, $r = .33$, $p = .04$. In contrast, lower loss aversion values on the cocaine valuation task were associated with higher loss aversion on the monetary mixed gambles task, $r = -.43$, $p = .01$. All other associations were not statistically significant, Mug-Monetary Gambles: $r = .08$; Mug-Cocaine Gambles: $r = .04$; Cocaine Valuation-Cocaine Gambles: $r = .16$; Monetary Gambles-Cocaine Gambles; $r = .31$.

Individual Differences in Loss Aversion

Table 3.3 contains associations between loss aversion outcomes and demographic and drug use variables. Mixed gambles λ values for both commodities were associated with self-reported days of past month cocaine use. Monetary gambles λ values were negatively associated with past month cocaine use. In contrast, cocaine gambles λ values were positively associated with past month cocaine use. Mug valuation λ values were also positively associated with self-reported alcoholic drinks per week. No other correlations between loss aversion and demographic and drug use variables were statistically significant.

Cocaine Purchase Task

One participant's data were non-systematic and removed from data analysis due to poor demand fit ($R^2 = .25$). Figure 3.3 shows the exponentiated model fit to mean cocaine demand (left) as well as the mean expenditure at each price (right). This model provided an excellent fit to mean consumption data ($R^2 = .99$) as well as individual consumption data (Mean $R^2 = .93$; SD = .05). Fits from the exponentiated model were

superior to the exponential model (Mean R^2 = .79; SD = .09) and this difference was statistically significant, t_{35} = 9.99, p < .001, d_z = 1.66. The correlation between derived (i.e., Q_0) and reported intensity of demand (i.e., consumption at free price) was also stronger for the exponentiated model, r = .89, than exponential model, r = .81, although both associations were statistically significant.

Table 3.4 contains means and standard deviations for cocaine purchase task outcomes and Table 3.5 contains associations between demand outcomes and loss aversion values. Cocaine λ values on the mixed gambles task were positively related to demand intensity and negatively related to demand elasticity. Cocaine λ values on the valuation task were positively related to breakpoint. Demand metrics were not significantly related to non-drug valuation or monetary mixed gambles outcomes.

Table 3.6 contains correlations between these demand parameters and demographic and drug use variables. Derived and graphical demand intensity were positively related to days of cocaine use and money spent on cocaine per month as well as DAST scores. O_{max} and P_{max} scores were also positively related to cigarette use variables. No other correlations were statistically significant.

Table 3.1 Loss Aversion Scores for Valuation Tasks

	WTA		WTP		Lambda (λ)			
Commodity	Mean	SD	Mean	SD	Mean	SD	*t*	*d*
Headphones	$7.05	$2.68	$7.55	$2.66	1.04*	0.50	11.83	1.92
Mug	$3.14	$1.74	$3.14	$1.81	1.15*	0.75	6.95	1.13
Cocaine	$75.26	$33.67	$70.00	$24.82	1.14*	0.58	9.10	1.48

Note. WTA = Willingness-to-Accept; WTP = Willingness-to-Purchase**.** * $p < .001$ comparing λ to a value of 2.

Table 3.2 Loss Aversion Scores for Mixed Gambles Tasks

	Loss Coefficient		Gain Coefficient		Lambda (λ)	
Commodity	Mean	SD	Mean	SD	Mean	SD
Money	-0.43	0.24	0.53	0.29	0.99*	0.66
Cocaine	-0.49	0.32	0.48	0.28	1.08*	0.59

Note. * $p < .001$ comparing λ to a value of 2.

Table 3.3 Semi-Partial Correlations Between Loss Aversion, Demographics, and Drug Use

						Cigarette Use		Alcohol Use		Cocaine Use	
	Age	Male	ZKPQ	Income	DAST	CPD	FTND	Drinks/ Week	MAST	Days/ Month	Money/ Month
Riskless											
Mug- λ	.18	-.18	.15	.15	-.13	-.01	-.10	**.41***	-.10	.14	-.05
Cocaine- λ	.04	.15	.02	-.11	.12	-.26	-.28	.04	.07	.18	.14
Risky											
Money- λ	-.01	.31	-.07	-.26	-.13	-.31	-.19	.01	.16	**-.38***	-.07
Cocaine- λ	-.01	-.15	.11	-.20	.13	-.20	.01	.03	-.04	**.41***	.11

Note. WTA = Willingness-to-Accept; WTP = Willingness-to-Purchase; Income = Yearly Income; ZKPQ = Impulsivity Subscale of the Zuckerman-Kuhlman Personality Questionnaire; DAST = Drug Abuse Screening Test; CPD = cigarettes per day; FTND = Fagerström Test for Nicotine Dependence; MAST = Michigan Alcohol Screening Test. Semi-partial correlations controlled for gain and loss constituents of the λ ratio. **Bold** = statistically significant correlation.

*$p < .05$; **$p < .01$

Table 3.4 Primary Outcomes on the Cocaine Purchase Task

Outcome	Mean	SD
Intensity	50.1	57.9
O_{max}	$516.4	$900.2
P_{max}	$54.4	$165.5
Breakpoint	$156.9	$273.2
Elasticity	.0036	.0089
Q_0	47.2	58.9
R^2	.93	.05

Note**.** Elasticity and Q_0 fit using the exponentiated demand model.

Table 3.5 Semi-Partial Correlations Between Cocaine Demand and Loss Aversion Outcomes

	Intensity	O_{max}	P_{max}	Breakpoint	Elasticity	Q_0
Riskless						
Mug-λ	<.01	-.20	-.24	-.14	.01	-.07
Cocaine-λ	.19	.25	.30	**.36***	-.20	-.05
Risky						
Money-λ	.08	-.20	-.18	-.18	.28	.14
Cocaine-λ	**.42***	.28	-.03	.19	**-.45***	**.38***

Note. Semi-partial correlations controlled for gain and loss constituents of the λ ratio. All demand metrics were log-transformed prior to analysis. **Bold** = statistically significant correlation.
*p < .05; **p < .01

Table 3.6 Spearman Correlations Between Demand Outcomes, Demographics, and Drug Use

						Cigarette Use		Alcohol Use		Cocaine Use	
	Age	Male	Income	ZKPQ	DAST	CPD	FTND	Drinks/ Week	MAST	Days/ Month	Money/ Month
Intensity	.04	.20	-.11	.08	**.43****	.26	.09	.09	-.05	**.48****	**.63****
O_{max}	.17	.13	.03	.30	.05	**.35***	.31	.01	.02	.24	.31
P_{max}	.27	-.11	.19	.22	-.13	.17	**.35***	-.15	-.05	-.15	-.01
Breakpoint	.22	.07	.29	.26	-.05	.30	.25	-.13	-.02	-.03	.16
Elasticity	.06	-.17	.01	-.17	.05	-.16	-.04	-.16	.06	-.22	-.20
Q_0	.11	.14	-.21	-.09	**.37***	.16	.08	.17	-.02	**.44****	**.51****

Note. Income = Yearly Income; CPD = cigarettes per day; ZKPQ = Impulsivity Subscale of the Zuckerman-Kuhlman Personality Questionnaire; DAST = Drug Abuse Screening Test; FTND = Fagerström Test for Nicotine Dependence; MAST = Michigan Alcohol Screening Test. All demand metrics were log-transformed prior to analysis. **Bold** = statistically significant correlation.

*$p < .05$; **$p < .01$

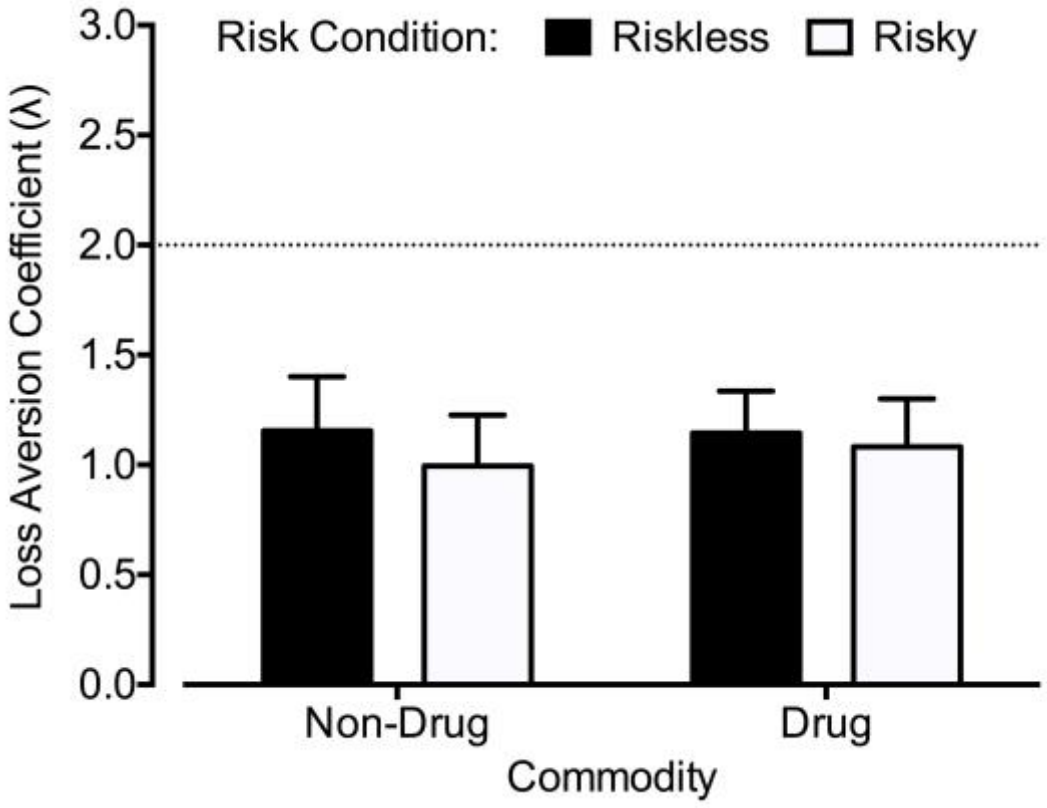

Figure 3.1 Loss aversion coefficients for valuation (black bars) and mixed gambles (white bars) tasks. Data represented from all included participants on each task (n = 31 to 38). Bars represent mean values and error bars represent 95% confidence intervals. Dotted line is placed at the normative loss aversion value of 2.

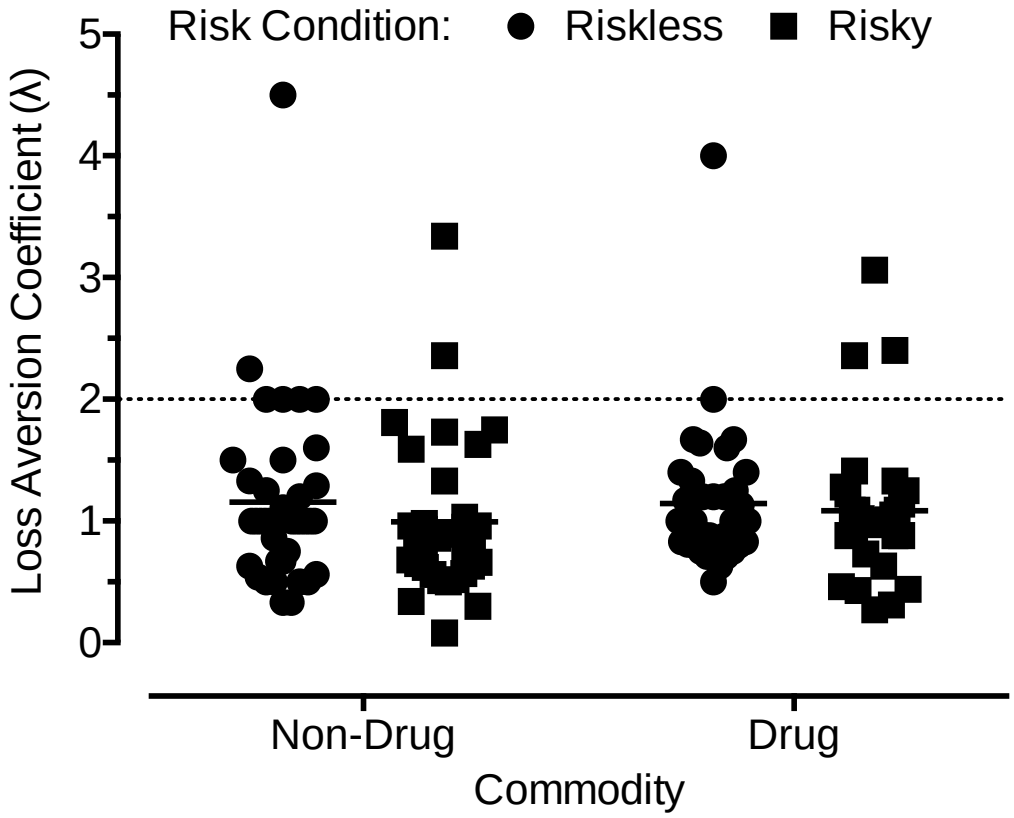

Figure 3.2 Individual participant data from valuation (circles) and mixed gambles (squares) tasks. Data represented from all included participants on each task (n = 31 to 38). Means represented by solid horizontal lines in each column of data. Dotted line is placed at the normative loss aversion value of 2.

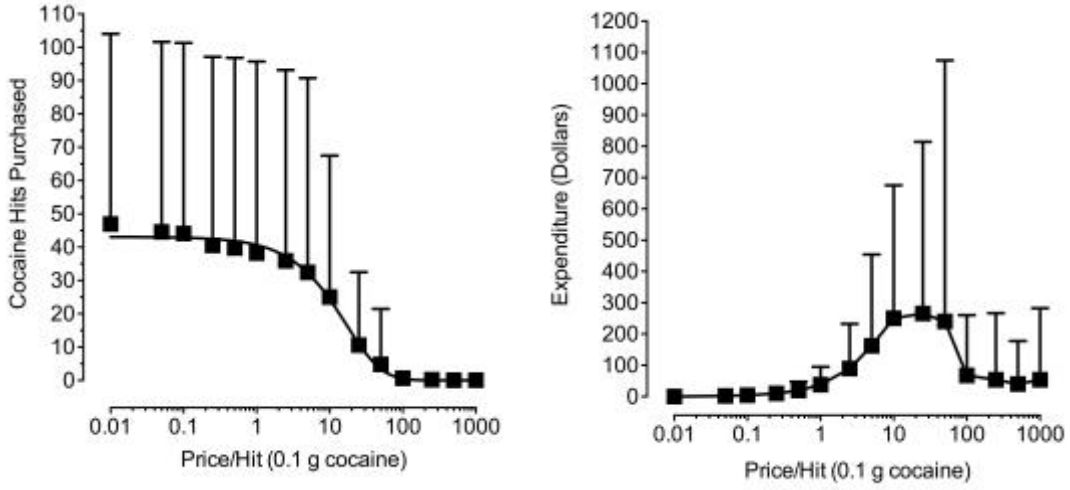

Figure 3.3 Economic demand for cocaine in active cocaine users (n = 37). Participants completed a cocaine purchase task in which hypothetical cocaine (0.1 g) was available. Price varied in United States dollars (USD) and hypothetical consumption measured. On the left is reported consumption plotted as mean (SD) group data on a log-linear axis fit using the exponentiated model (Equation 1 shown in the Methods). On the right is reported expenditure plotted as mean (SD) group data.

Chapter 4: Discussion

The purpose of the present study was to evaluate loss aversion in active cocaine users. Cocaine users showed a robust and reliable reduction in loss aversion when compared to standard values obtained in the general population. This difference was observed across multiple tasks designed to evaluate loss aversion under conditions of certainty and conditions of risk. Attenuated loss aversion was also consistent across commodities, including non-drug (e.g., money) and hypothetical drug (e.g., cocaine) commodities. Hypothetical demand for cocaine decreased with increases in price and this relationship was well explained by mathematical models of demand. More intense and inelastic cocaine demand was associated with greater loss aversion for cocaine. These data represent the first comprehensive study on multiple dimensions of loss aversion in a substance using population and suggest that reductions in loss aversion are associated with a history of cocaine use.

Participants reported similar sensitivities to gains and losses across conditions of certainty and risk as well as for drug and non-drug commodities. This absence of loss aversion, as indicated by λ values of 1, was remarkably consistent across all experimental conditions. These results are even more striking considering that inspection of individual data revealed few exceptions to this trend. Equally important to note is that the absence of loss aversion could not be attributed to the study's within-subjects design. A between-subject analysis using only data from the first task completed did not reveal statistically significant differences in the prices for selling and buying conditions. This analysis also indicated λ values similar to the within-subject comparison. This consistency is important because between-subjects manipulations analogous to this between-subject analysis are traditionally used to generate WTP, WTA, and λ values with valuation tasks (e.g., Kahneman et al., 1990; Novemsky & Kahneman, 2005).

A uniform response to gains and losses stands in direct contrast to the rich behavioral economic literature demonstrating that losses generally have a greater impact on behavior than gains (Kahneman & Tversky, 1979; Morewedge & Giblin, 2015; Tversky & Kahneman, 1991, 1992). The established 2:1 sensitivity of losses to gains (λ = 2) has been observed across a variety of experimental conditions, including the valuation and mixed gambles tasks used here (e.g., Gachter et al., 2007; Kahneman et al., 1990; Tom et al., 2007). Although controls were not explicitly recruited in the current study, comparison of the observed λ values to this normative and accepted value of 2 in the general population revealed statistically significant differences that were large in effect size. The robust nature of this difference combined with the consistency across and within experimental conditions provides convincing evidence for an attenuation of loss aversion in this cocaine-using population.

Reliable correlations among measures of loss aversion were not observed. In fact, loss aversion for cocaine on the valuation task was negatively correlated with loss aversion for money on the mixed gambles task. Analysis of individual data revealed a high degree of homogeneity and clustering for λ values on each loss aversion task. It is possible that a low degree of variability resulted in range restriction and attenuation for the observed associations. Follow up studies could address this concern by recruiting individuals with more varied drug use and explore the relationship between loss aversion and different translational stages of cocaine misuse (e.g., recreational use, dysregulated use, abstinence, relapse, and recovery) or by studying individuals who report use of other drugs (e.g., opioids or cannabis).

Economic demand for cocaine was effectively and efficiently measured using a hypothetical cocaine purchase task. Demand for cocaine systematically decreased with increases in price and was well explained by the exponentiated demand equation for a majority of participants (97.4%). The exponentiated model has recently been introduced

as an alternative to the typically used exponential model because it can incorporate the zero consumption values commonly observed with human purchase task data (whereas the exponential model cannot; Koffarnus et al., 2015; Strickland et al., in press). The current experiment provides additional support for the utility of the exponentiated model by demonstrating superior demand fit and association between self-reported and model-derived measures of demand intensity. Cocaine demand parameters were also associated with measures of cocaine use (e.g., days used cocaine per month), consistent with other studies using alcohol and cigarette purchase tasks. These findings lend additional support for the construct validity of purchase task techniques for measuring cocaine use. Future research will be needed to evaluate the predictive validity of this measure for evaluating behavioral and pharmacological interventions for cocaine use disorder.

More inelastic and intense cocaine demand was associated with greater loss aversion for cocaine on the mixed gambles task. Higher breakpoints were also associated with greater loss aversion on the cocaine valuation task. Relatedly, more frequent cocaine use was associated with higher loss aversion for cocaine and lower loss aversion for money on the mixed gambles tasks. These results collectively indicate that problematic cocaine use is positively associated with loss aversion for drug and negatively associated with loss aversion for non-drug commodities. This finding is consistent with the idea that problematic and prolonged substance use involves an increased focus on drug consumption coupled with a decreased attention to the negative consequences caused by that use (i.e., the loss of non-drug commodities; American Psychiatric Association, 2013). Future studies will be needed to further evaluate the association between drug demand, loss aversion, and traditional measures of drug-taking behavior to replicate and clarify these relationships.

The current findings are congruent with the results of prior studies on loss aversion conducted in illicit drug users (e.g., Ahn et al., 2014; Fridberg et al., 2010; Vassileva et al., 2013). These studies have generally reported outcomes consistent with decreases in loss aversion by using computational modeling combined with IGT data. In one such study, chronic cannabis users showed attenuated loss aversion on the IGT relative to matched controls (Fridberg et al., 2010). Similar outcomes were reported in a later study with heroin-dependent patients in extended abstinence (> 3 months; Ahn et al., 2014). Most studies in cocaine users also report findings suggestive of decreases in loss aversion that are consistent with the present finding (Stout et al., 2004; Vassileva et al., 2013). For example, drug use in a sample of HIV-positive women (that included a subset of individuals reporting cocaine use) was associated with diminished loss aversion on the IGT (Vassileva et al., 2013). It is important to note that the above findings were collected with an indirect measure of loss aversion (i.e., computational modeling of IGT performance) that is not traditionally used in behavioral economic research. This discrepancy makes comparisons to the broader behavioral economic literature difficult. A study presented at the 2014 annual meeting of the College on Problems of Drug Dependence reported enhanced loss aversion in HIV-positive cocaine users on a task similar to the mixed gambles task used here (Meade et al., 2014). The reasons for the discordance between these findings and the present study are not known; however, it is possible that HIV comorbidity in this other sample influenced the experimental outcomes. It is also important to recognize that these findings have not been published in a peer-reviewed format and only represent a preliminary data analysis. Thus, the results from the majority of previous research in substance using populations coupled with the present findings suggest that drug use is associated with the decreased and possible absence of loss aversion.

A review of laboratory studies conducted in other clinical populations offers several behavioral and neurobiological mechanisms that may underlie the absence of loss aversion observed in cocaine users. Problem gamblers, for example, have generally shown similar decreases in loss aversion (Brevers et al., 2012; Lorains et al., 2014; but see Giorgetta et al., 2014). These decreases have been reported in non-treatment seeking gamblers (Brevers et al., 2012) as well as those in outpatient treatment (Lorains et al., 2014). High rates of comorbidity are observed between problem gambling and substance use, with some suggesting that dysregulation in impulsive behavior is the common trait underlying these disorders (Lorains, Cowlishaw, & Thomas, 2011; Peters et al., 2015; Verdejo-Garcia, Lawrence, & Clark, 2008). It is possible that changes in impulsive behavior also represent the behavioral mechanism underlying the decreased loss aversion observed in these populations. Although the relationship between impulsive behavior and loss aversion has not been extensively examined, preliminary evidence obtained in adolescents suggests that higher rates of impulsivity are associated with decreases in loss aversion (Ernst et al., 2014). A correlation between loss aversion and the impulsivity subscale of the ZKPQ was not observed in this study. Self-report measures like the ZKPQ likely reflect broader indicators of trait personality rather than specific and individual types of impulsive behavior (de Wit, 2009; Reynolds, Ortengren, Richards, & de Wit, 2006). These measures also require the participant to accurately assess behavior over a variety of situations and typically only show modest correlation with more direct behavioral measures (Cyders & Coskunpinar, 2011; de Wit, 2009; Reynolds et al., 2006). The use of methods that examine specific behavioral constructs of impulsive behavior (e.g., delay discounting; response inhibition) in future studies will be important for evaluating the functional relationship between impulsivity and loss aversion.

Reductions in loss aversion are also consistently observed in individuals with schizophrenia (Brown et al., 2013; Kim, Kang, & Lim, 2016; Tremeau et al., 2008). For example, patients with schizophrenia have failed to show loss aversion in a valuation task similar to the one used here ($\lambda = 0.87$; Tremeau et al., 2008). Individuals with schizophrenia also show impaired assessment of expected value on a mixed gambles task (Brown et al. 2013). Dopaminergic theories of schizophrenia posit that dysfunction in presynaptic dopaminergic terminals contributes to the development and persistence of the disorder (see review by Howes, McCutcheon, & Stone, 2015). Chronic cocaine use also results in functional alterations in the dopaminergic system, including downregulation of dopamine D_2 receptors and a hypo-dopaminergic state (Goldstein et al., 2010; Volkow et al., 1996). Disrupted and aberrant signaling in the dopamine system could represent a neurobiological mechanism mediating decreased loss aversion. In fact, neuroimaging research suggests that regions in the mesolimbic dopamine system play a role in loss aversion (Tom et al., 2007). Participants in that study completed a mixed gambles task while fMRI techniques were used to evaluate the neural systems activated during gains and losses. It was found that loss anticipation produced deactivation in mescorticolimibic structures and that this diminished neural sensitivity was associated with decreased loss aversion. Recent evidence that links functional polymorphisms in BDNF and ANKK1 genes to changes in loss aversion also supports this dopamine hypothesis (Voigt, Montag, Markett, & Reuter, 2015). Specifically, participants in that study with polymorphisms related to decreased BDNF secretion and D_2 receptor density and binding reported the lowest loss aversion scores. Follow-up studies are needed to test this dopamine hypothesis because similar behavioral phenotypes (e.g., reduced loss aversion) may arise from distinct neurobiological mechanisms. Pharmacological manipulations directly targeting the dopaminergic system (e.g., acute amphetamine and/or haloperidol challenge) and additional neuroimaging

studies evaluating both structure and function in combination with behavior could help elucidate the role of dopamine in mediating the expression of loss aversion.

Loss aversion has also been implicated in limbic system function and, in particular, amygdala activity. For example, damage to the amygdala abolishes behavioral expression of loss aversion under risky conditions (De Martino et al., 2010). In that study, two patients with focal bilateral amygdala lesions completed a mixed gambles task and performance compared to matched controls. Dramatic attenuation of loss aversion was observed in these patients despite no differences in risk aversion or expected value computation (i.e., preference for larger gains and smaller losses). Loss aversion on mixed gambles tasks is also associated with differential amygdala activity following losses and gains in healthy participants (Sokol-Hessner, Camerer, & Phelps, 2013). Participants in that study were healthy, college students who completed a mixed gambles task combined with fMRI. Greater BOLD activity in the amygdala in response to losses relative to gains was associated with greater expression of loss aversion (i.e., higher λ values).

These findings suggest a potential arousal mechanism involved in loss aversion given the role that the amygdala and the greater limbic structures play in regulating arousal and emotion. Support for this hypothesis comes from skin conductance studies that have demonstrated greater autonomic response to losses than gains and that these differences are positively associated with loss aversion (i.e., greater autonomic response to loss than gain is correlated with greater loss aversion; Sokol-Hessner et al., 2009; Wu, Van Dijk, Aitken, & Clark, 2016). An autonomic arousal mechanism is also supported by a recent study in which administration of the β-adrenergic receptor antagonist propranolol reduced loss aversion, but had no effect on risk sensitivity or choice consistency (Sokol-Hessner et al., 2015). Awareness of one's arousal also likely contributes to loss aversion because interoception (i.e., sensitivity to internal

physiological states) positively correlates with loss aversion (Sokol-Hessner, Hartley, Hamilton, & Phelps, 2015). In that study, performance on a heartbeat-detection task used to measure interoceptive ability was positively correlated with loss aversion on a mixed gambles task. Interoceptive performance was not associated with risk response or choice consistency indicating that the relationship was specific to loss aversion.

The association between interoception, limbic system function, and loss aversion is notable given recent arguments that addictive behaviors are functionally tied to dysregulated interoceptive activity, deficits in arousal, and disrupted activity in the insular cortex (see reviews by Paulus & Stewart, 2014; Paulus, Tapert, & Schulteis, 2009). Cocaine use is related to changes in amygdala structure and function, including decreases in overall volume and binding potential (e.g., Makris et al., 2004; Milella et al., 2014). More broadly, cocaine use is associated with decreases in mesocorticolimbic system volume and reduced functional connectivity among system circuits (e.g., Gu et al., 2010; Hu, Salmeron, Gu, Stein, & Yang, 2015; Rando, Tuit, Hannestad, Guarnaccia, & Sinha, 2013). Few studies have systematically examined interoception in cocaine users, but some data exists suggesting compromised interoceptive awareness and alterations in the structure and function of the insular cortex (e.g., Cisler et al., 2013; Ersche et al., 2014; Stewart, Juavinett, May, Davenport, & Paulus, 2015). More work is needed, however, to understand possible changes in interoceptive awareness among cocaine users and how these changes might relate to loss aversion.

Several limitations of the current study should be noted. First, these data represent a cross-sectional analysis of loss aversion in current cocaine users. Longitudinal studies are necessary for differentiating those effects that are antecedent to and those that are a consequence of cocaine use. Such findings will help determine if loss aversion represents a predisposing/risk factor for developing a cocaine use disorder or is a result of a history of cocaine use (or, most likely, a combination of the two). Such a distinction

is crucial for determining to what extent loss aversion may provide a behavioral marker for substance use diagnosis and assessment.

Second, comparisons between the monetary and cocaine mixed gambles tasks should be made with caution because the ranges of gains and losses, outcomes of decisions (i.e., real versus hypothetical), and qualitative nature of the commodities (i.e., dollars versus grams) were different. Of particular note, a recent study found that the gain and loss ranges used on mixed gambles tasks can influence the derived loss aversion coefficient (Walasek & Stewart, 2015). Participants in that study were randomly assigned to complete mixed gambles tasks with varying distributions of gains and losses. Discrepant loss aversion outcomes were observed with each of these range conditions, including the expression of loss aversion, absences of loss aversion, and reverse of loss aversion ($\lambda < 1$). The gain and loss ranges used in the present study were identical to a range that produced loss aversion in the aforementioned study ($\lambda = 1.93$; Walasek & Stewart, 2015) as well as other demonstrations of loss aversion in healthy participants ($\lambda = 1.93$; Tom et al., 2007). Thus, it is unlikely that the lower loss aversion observed on the mixed gambles task was due to this methodological variable.

Third, it is unclear how loss aversion might relate to other behavioral mechanisms implicated in substance use disorders. The current study evaluated economic demand for cocaine, but did not include other common principles studied in the behavioral economic and substance use literatures (e.g., delay discounting, status quo bias; Chivers & Higgins, 2012). As noted above, a rich body of literature has demonstrated the relationship between drug use and delay discounting (Bickel et al., 2012). It is possible that loss aversion and delay discounting represent related behavioral phenomenon that are similarly related to substance use disorders. However, it is also possible that these principles represent non-overlapping constructs that uniquely predict drug use. Future

research could include additional behavioral economic measures in order test such predictions.

Fourth, a substantial proportion of data were excluded from the mixed gambles task due to the inability to effectively generate loss aversion coefficients. Model convergence was not possible or stable in many of these cases due to the high proportion of gambles accepted by some participants (e.g., acceptance of all or nearly all gambles). High rates of gamble acceptance could be indicative of confusion about the task and its outcomes. Alternatively, these data could indicate extreme loss aversion (or lack thereof) in which any loss, no matter how large or small, is ineffective at changing behavior. Supporting this hypothesis, excluded participants reported higher rates of cocaine use and greater nicotine dependence. Additional comparisons made using linear mixed-effects models that allowed for inclusion of participants with missing data did not result in qualitatively different outcomes. Analysis of data from the valuation tasks also indicated that these excluded participants did not differ on WTA, WTP, or λ values meaning that their exclusion from some analyses was unlikely to have systematically biased study outcomes.

Finally, it is possible that changes in loss aversion are epiphenomenally related to other primary causal agent(s) implicated in substance use disorders. For example, socioeconomic status (SES) is frequently tied to drug use and other adverse health behaviors (Galea & Vlahov, 2002; Gilman, Abrams, & Buka, 2003). Although few studies have systematically studied the relationship between loss aversion and SES, the existing literature suggests that lower SES is correlated with lower loss aversion (Gachter et al., 2007). Participants in the present sample reported a mean yearly income that was below the poverty threshold (Mean = $7155/year), however, income was not related to the magnitude of loss aversion. It is possible that differences in SES between populations rather than within this population might explain the lower loss aversion observed relative

to individuals typically sampled in loss aversion studies (e.g., undergraduate and graduate-level college students). Future studies will be needed to evaluate SES and other alternative explanations for the relationship between loss aversion and substance use.

Loss aversion could provide important translational implications for treatment and interventions development. If loss aversion represents a behavioral mechanism underlying the disadvantageous choices characteristic of substance use disorders, then altering this bias could result in reciprocal changes in drug-taking behavior. This possibility is not unwarranted given that loss aversion is sensitive to cognitive-regulation strategies (Sokol-Hessner et al., 2009). For example, participants who engage in a regulation strategy that emphasizes choices in isolation show greater loss aversion than those engaged in a strategy that emphasizes choices in a broader setting (Sokol-Hessner et al., 2009). Incorporating cognitive strategies designed to change loss aversion in the context of other interventions, such as cognitive-behavioral therapy, might provide an efficient means to modify drug-taking behavior.

Loss aversion is also closely tied to CM and the framing of incentives as gains or losses. Reinforcers delivered in CM may be framed as either a gain contingent on the presence of a desired behavior (e.g., positive reinforcement) or as a loss due to the absence of a desired behavior (e.g., negative reinforcement; contract based approaches). The present findings suggest a uniform sensitivity to loss and gain that may make both forms of incentive framing in CM equally effective. Additional tests are needed to determine if loss aversion may provide a putative moderator of CM efficacy and allow for patient-level tailoring of CM designs.

Prospect theory and loss aversion were first introduced to explain deviations from traditional economic theory and the idea that a rational decision maker makes decisions based on expected utility. Participants in the present study unexpectedly operated under

conditions more closely aligned with an expected utility hypothesis than the “irrational” agent described by prospect theory. The reported loss aversion values (i.e., λ) of one suggest an equal sensitivity to losses and gains (i.e., loss equivalence) that is predicted by an expected utility model of choice. For example, decisions in the mixed gambles task approximated decision-making based on expected utility (e.g., indifference at an expected value of zero). That cocaine users displayed rational economic choice is consistent with the growing body of literature challenging the assumption that individuals with substance use disorders exhibit extensive cognitive impairment and uncontrollable, irrational behavior (e.g., Hart, Marvin, Silver, & Smith, 2012). Decisions based on expected utility and made with a proportional weight given to gains and losses are often desirable and advantageous (e.g., in market trading, investing, gambling). However, loss equivalence may also decrease the appropriate attention needed to harmful consequences that loss aversion may otherwise protect against (e.g., the decision to use drugs despite the negative health, social, and/or economic consequences). It is possible that this inattention contributes to the impaired insight into drug use and need for treatment that often impede intervention efforts in substance-using populations. Addressing loss aversion in this respect may help improve awareness and evaluation of the negative consequences of drug use to encourage treatment-seeking behavior and improve retention in existing interventions.

The current findings expand the extant literature on the intersection of behavioral economics and addiction science by using multi-method, within-subjects techniques to study loss aversion in cocaine users. There have been no studies conducted using the valuation task in substance-using populations. Similarly, no studies have used the ecological relevant commodity of abused drugs when examining loss aversion. Reliable and robust evidence for decreased loss aversion in cocaine users was observed and several behavioral and neurobiological mechanisms consistent with these results were

identified. Research examining these putative mechanisms and the functional relationship between loss aversion and drug-taking behavior will be crucial for the future of loss aversion in directing treatment and interventions development efforts.

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Walasek, L., & Stewart, N. (2015). How to make loss aversion disappear and reverse: tests of the decision by sampling origin of loss aversion. *J Exp Psychol Gen, 144*(1), 7-11. doi:10.1037/xge0000039

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Wu, Y., Van Dijk, E., Aitken, M., & Clark, L. (2016). Missed losses loom larger than missed gains: Electrodermal reactivity to decision choices and outcomes in a gambling task. *Cogn Affect Behav Neurosci, 16*(2), 353-361. doi:10.3758/s13415-015-0395-y

VITA

JUSTIN CHARLES STRICKLAND

EDUCATION

Davidson College — 2010-2014
B.S., Summa Cum Laude, Major in Psychology, Major in Biology — Davidson, NC
First Honor; High Honors in Psychology

TRAINING AND PROFESSIONAL EXPERIENCE

University of Kentucky Laboratory of Human Behavioral Pharmacology — 2014-Present
Graduate Research Student — Lexington, KY

Davidson College Behavioral Pharmacology Laboratory — 2011-2014
Student Researcher — Davidson, NC

Davidson College Herpetology Laboratory — 2013-2014
Student Researcher — Davidson, NC

Davidson College Development Neurobiology Laboratory — 2013-2014
Student Researcher — Davidson, NC

Davidson College Social Psychology Laboratory — 2012-2013
Student Researcher — Davidson, NC

HONORS, AWARDS, AND FELLOWSHIPS

Grants and Fellowships

National Science Foundation Graduate Research Fellowship — 2014-2019
University of Kentucky Graduate School Multiyear Fellowship — 2014-2016
University of Kentucky Lipman Fellowship — 2014-2016
Psi Chi Graduate Research Grant — 2016
University of Kentucky Pilot Grant — 2014
Davidson College George L. Abernethy Grant — 2013
Barry Goldwater Scholarship — 2013
Davidson College Research Initiative Fellowship — 2012

Departmental and University Honors

University of Kentucky Royster Award of Special Distinction — 2014-2017
Davidson College William Gatewood Workman Award — 2014
Davidson College Sigma Xi Research Award — 2014
Davidson College Tom Daggy Biology Award — 2014
Davidson College Alumni Association Award — 2011

Conference and Travel Awards

American Psychological Association Student Travel Award — 2016
Behavior, Biology, and Chemistry Conference Student Travel Award — 2016
European Behavioural Pharmacology Society Student Travel Award — 2015
American Psychological Association Student Travel Award — 2015

American Psychological Association Early Career Travel Award	2015
Behavior, Biology, and Chemistry Conference Outstanding Poster Presentation	2015
Behavior, Biology, and Chemistry Conference Student Travel Award	2015
Association of South Eastern Biologists Student Research Award	2014

PUBLICATIONS

Peer-Reviewed Manuscripts

1. **Strickland JC**, Lile JA, Rush CR, and Stoops WW (in press) Comparing exponential and exponentiated models of drug demand in cocaine users. *Experimental and Clinical Psychopharmacology*.
2. **Strickland JC** and Smith MA (in press) Animal models of resistance exercise and their application to neuroscience research. *Journal of Neuroscience Methods*
3. Smith MA and **Strickland JC** (in press) Modeling the impact of social contact on substance use. *Neuropsychopharmacology Reviews*
4. **Strickland JC**, Reynolds AR, and Stoops WW (2016) Regulation of craving by cognitive strategies in an online sample of cocaine users. *Psychology of Addictive Behaviors, 30*, 607-612
5. Lacy RT, **Strickland JC**, Feinstein MA, Robinson AM, and Smith MA (2016) The effects of sex, estrous cycle, and social contact on cocaine and heroin self-administration. *Psychopharmacology, 233*, 3201-3210
6. **Strickland JC**, Bolin BL, Lile JA, Rush CR, and Stoops WW (2016) Differential sensitivity to learning from positive and negative outcomes in cocaine users. *Drug and Alcohol Dependence, 166*, 61-68
7. Robinson AM, Lacy RT, **Strickland JC**, and Smith MA (2016) The effects of social contact on cocaine intake under extended-access conditions in male rats. *Experimental and Clinical Psychopharmacology, 24*, 285-296
8. **Strickland JC**, Abel JM, Lacy RT, Beckmann JS, Witte MA, Lynch WJ, and Smith MA (2016) The effects of resistance exercise on cocaine self-administration, muscle hypertrophy, and BDNF expression in the nucleus accumbens. *Drug and Alcohol Dependence, 163*, 186-194
9. **Strickland JC**, Pinheiro AP, Cecala KK, and Dorcas ME (2016) Relationship between behavioral thermoregulation and physiological function in larval stream salamanders. *Journal of Herpetology*, *50*, 239-244
10. Stoops WW, **Strickland JC**, Hays LR, Rayapati AO, Lile JA, and Rush CR (2016) Safety and tolerability of intranasal cocaine during phendimetrazine maintenance. *Psychopharmacology, 233*, 2055-2063
11. **Strickland JC**, Feinstein MA, Lacy RT, and Smith MA (2016) The effects of physical activity on impulsive choice: Differential effects on sensitivity to reinforcement amount and delay. *Behavioural Processes, 126*, 36-45
12. **Strickland JC** and Stoops WW (2015) Perceptions of research risk and undue influence: Implications for ethics of research conducted with cocaine users. *Drug and Alcohol Dependence, 156*, 304-310
13. **Strickland JC** and Smith MA (2015) Animal models of social contact and drug self-administration. *Pharmacology, Biochemistry, and Behavior, 136*, 47-54
14. **Strickland JC**, Wagner FP, Stoops WW, and Rush CR (2015) Profile of Internet access in active cocaine users. *The American Journal on Addictions, 24*, 582-585

15. Smith MA, **Strickland JC**, Bills SE, and Lacy RT (2015) The effects of a shared history of drug exposure on social choice. *Behavioral Pharmacology, 26*, 631-635
16. **Strickland JC**, Rush CR, and Stoops WW (2015) Mu opioid mediated discriminative-stimulus effects of tramadol: An individual subjects analysis. *Journal of the Experimental Analysis of Behavior, 103*, 361-374
17. **Strickland JC**, Bahram CH, Harden L, Pittman SE, Kern MM, and Dorcas ME (2015) Life-history costs of reproductive behaviors in a wetland-breeding amphibian. *Journal of Freshwater Ecology, 30*, 435-444
18. Lacy RT, **Strickland JC**, Brophy MK, Witte MA, and Smith MA (2014) Exercise decreases speedball self-administration. *Life Sciences, 114*, 86-92
19. Lacy RT, **Strickland JC**, and Smith MA (2014) Cocaine self-administration in social dyads using custom-built operant conditioning chambers. *Journal of Neuroscience Methods, 236,* 11-16
20. **Strickland JC**, Lile JA, Rush CR, and Stoops WW (2014) Relationship between intranasal cocaine self-administration and subject-rated effects: Predictors of cocaine taking on progressive ratio schedules. *Human Psychopharmacology: Clinical and Experimental, 29,* 342-350
21. **Strickland JC** and Smith MA (2014) The anxiolytic effects of resistance exercise. *Frontiers in Psychology: Movement Science and Sport Psychology, 753*
22. Smith MA, Lacy RT, and **Strickland JC** (2014) The effects of social learning on the acquisition of drug self-administration. *Drug and Alcohol Dependence, 141*, 1-8
23. **Strickland JC** and Smith MA (2014) The effects of social contact on drug use: Behavioral mechanisms controlling drug intake. *Experimental and Clinical Psychopharmacology, 22,* 23-34
24. Peitz GW, **Strickland JC**, Pitts EG, Foley M, Tonidandel S, and Smith MA (2013) Peer influences on drug self-administration: An econometric analysis in socially housed rats. *Behavioural Pharmacology, 24,* 114-123

Encyclopedia Entries and Book Reviews

1. **Strickland JC** (in press) Nonparametric statistics. *The SAGE Encyclopedia of Industrial and Organizational Psychology, 2nd edition*
2. **Strickland JC** (2014) Textbook review: Guide to research techniques in neuroscience. *The Journal of Undergraduate Neuroscience Education, 13,* R1-R2

Posters and Presentations

Oral Presentations

1. **Strickland JC*** (2016) Emerging reforms in psychological science: How the changing face of scientific research may Influence your research. Symposium at the 124th annual meeting of the American Psychological Association: Denver, CO

   ***Symposium Chair**
2. **Strickland JC**, Rush CR, and Stoops WW (2016) Influence of cocaine cues on monetary choice in cocaine users. Oral presentation at the 78th annual meeting of the College on Problems of Drug Dependence: Palm Springs, CA
3. **Strickland JC** (2016) Using Amazon's Mechanical Turk (mTurk) to sample substance using populations. Invited workshop presentation at the 78th annual meeting of the College on Problems of Drug Dependence: Palm Springs, CA
4. Harvanko AM, **Strickland JC**, and Reynolds BA (2016) Predicting contingency management treatment efficacy by using measures of impulsivity. Oral presentation

at the 78th annual meeting of the College on Problems of Drug Dependence: Palm Springs, CA

5. Robinson AM, Lacy RT, **Strickland JC**, Magee CP, and Smith MA (2016) The effects of social contact on "binge" cocaine self-administration. Oral presentation at the 78th annual meeting of the College on Problems of Drug Dependence: Palm Springs, CA
6. Putka DJ, **Strickland JC**, and Tonidandel S (2016) Estimating relative weights in the face of model selection uncertainty. Oral presentation at the 31st annual conference of the Society for Industrial and Organizational Psychology: Anaheim, CA
7. **Strickland JC**, Rush CR, and Stoops WW (2015) Contribution of conditioned drug action to cocaine self-administration. Oral presentation at the satellite meeting of the International Study Group Investigating Drugs as Reinforcers: Phoenix, AZ
8. Smith MA, **Strickland JC**, Lacy RT, Witte MA, Abel JM, and Lynch WJ (2015) The effects of strength training on the positive reinforcing effects of cocaine. Oral presentation at the 59th annual meeting of the Behavioral Pharmacology Society: Boston, MA
9. Lacy RT, **Strickland JC**, and Smith MA (2014) The effects of social learning on the acquisition of drug self-administration. Oral presentation at the satellite meeting of the International Study Group Investigating Drugs as Reinforcers: San Juan, Puerto Rico
10. **Strickland JC***, Pinheiro AP, Cecala KK, and Dorcas ME (2014) Physiological constraints to respond to climate change: Insights from the effects of temperature on standard metabolic rate in larval salamanders. Oral presentation at the 75th annual meeting of the Association of Southeastern Biologists: Spartanburg, SC
    ***Awarded Student Research Award**
11. **Strickland JC** (2013) Effects of resistance exercise on the positive reinforcing effects of cocaine. Oral presentation at the 2013 Wake Forest-Emory Lab Exchange: Atlanta, GA
12. **Strickland JC**, Nyein, KP, White TE, and Good JJ (2013) The effects of Good Samaritan law awareness on helping behavior. Oral presentation at the 38th annual Carolina's Psychology Conference: Raleigh, NC

Poster Presentations

1. **Strickland JC** and Stoops WW (2016) Latent factor structure of cocaine demand in an online sample of cocaine users. Poster presentation at the 124th annual meeting of the American Psychological Association: Denver, CO
2. Wagner FP, Romanelli MR, **Strickland JC**, Lile JA, Stoops WW, and Rush CR (2016) Relationship between age of drug use initiation and self-reported ADHD symptoms in cocaine users. Poster presentation at the 124th annual meeting of the American Psychological Association: Denver, CO
3. **Strickland JC**, Lile JA, Rush CR, and Stoops WW (2016). Sensitivity to reinforcement and punishment learning in active cocaine users. Poster presentation at the 8th annual Behavior, Biology, and Chemistry: Translational Research in Addiction Conference: San Antonio, TX
4. **Strickland JC** and Stoops WW (2015) Perceptions of research risk and undue influence in an online sample of cocaine users. Poster presentation at the 16th annual meeting of the European Behavioral Pharmacology Society: Verona, Italy
5. Magee CP, Lacy RT, Robinson AM, **Strickland JC**, and Smith MA (2015) The effects of social contact on "binge" cocaine self-administration. Poster presentation at

the 23rd annual Faculty for Undergraduate Neuroscience Satellite Event at the Society for Neuroscience: Chicago, IL

6. **Strickland JC**, Stoops WW, and Rush CR (2015) The association between intranasal methamphetamine self-administration and subject-rated effects. Poster presentation at the 123rd annual meeting of the American Psychological Association: Toronto, Canada
7. Lacy RT, **Strickland JC**, Bills SE, and Smith MA (2015) A shared history of drug exposure influences social preference. Poster presentation at the 123rd annual meeting of the American Psychological Association: Toronto, Canada
8. **Strickland JC**, Stoops WW, and Rush CR (2015) The relationship between methamphetamine self-administration and subject-rated effects. Poster presentation at the 77th annual meeting of the College on Problems of Drug Dependence: Phoenix, AZ
9. Wagner F, **Strickland JC**, Stoops WW, and Rush CR (2015) Feasibility of web-based treatment delivery for cocaine use disorder: Profile of Internet access by active cocaine users. Poster presentation at the 77th annual meeting of the College on Problems of Drug Dependence: Phoenix, AZ
10. Lacy RT, Feinstein MA, **Strickland JC**, and Smith MA (2015) The effects of estrous cycling on cocaine self-administration in socially housed male-female dyads. Poster presentation at the 77th annual meeting of the College on Problems of Drug Dependence: Phoenix, AZ
11. **Strickland JC***, Rush CR, and Stoops WW (2015) Discriminative-stimulus effects of tramadol: An individual subjects analysis of mu opioid-receptor mediated effects. Poster presentation at the 7th annual Behavior, Biology, and Chemistry: Translational Research in Addiction Conference: San Antonio, TX
    ***Awarded Outstanding Poster Presentation**
12. **Strickland JC**, Lacy RT, Brophy MK, Witte MA, and Smith MA (2014) Aerobic exercise decreases speedball self-administration in female rats. Poster presentation at the 76th annual meeting of the College on Problems of Drug Dependence: San Juan, Puerto Rico
13. Smith MA, Lacy RT, and **Strickland JC** (2014) The effects of social learning on the acquisition of cocaine self-administration. Poster presentation at the 76th annual meeting of the College on Problems of Drug Dependence in San Juan, Puerto Rico
14. Bahram CH, **Strickland JC**, Harden LA, Pittman SE, Kern MM, and Dorcas ME (2014) Influence of sex and migration behavior on reproductive cost of spotted salamander. (*Ambystoma maculatum*). Poster presentation at the 75th annual meeting of the Association of Southeastern Biologists: Spartanburg, SC
15. Smith MA, **Strickland JC**, Pitts EG and Witte MA (2013) The effects of forced running procedures on the self-administration of cocaine. Poster presentation at the 1st annual meeting of Collaborative Perspectives on Addiction: Atlanta, GA
16. Smith MA, **Strickland JC**, and Witte MA (2013) The effects of strength training on cocaine self-administration. Poster presentation at the 75th annual meeting of the College on Problems of Drug Dependence: San Diego, CA
17. **Strickland JC**, Witte MA, and Smith MA (2013) The effects of exercise on cocaine self-administration: Role of strength and resistance training. Poster presentation at the 7th annual Symposium for Young Neuroscientists and Professors of the SouthEast: Columbia, SC
18. **Strickland JC** and Smith MA (2012) The effects of forced running procedures on the self-administration of cocaine. Poster presentation at the 20th annual Faculty for

Undergraduate Neuroscience Satellite Event at the Society for Neuroscience: New Orleans, LA

19. Smith MA, Pietz GW, **Strickland JC**, Pitts EG, Tonidandel S, and Foley MC (2012) Peer influences on drug self-administration: An econometric analysis in socially housed rats. Poster presentation at the 42nd annual meeting of the Society for Neuroscience: New Orleans, LA
20. **Strickland JC**, Pitts EG, and Smith MA (2012) The relationship between exercise duration and the positive reinforcing effects of cocaine. Poster presentation at the 6th annual Symposium for Young Neuroscientists and Professors of the SouthEast: Columbia, SC
21. **Strickland JC** and Smith MA (2011) The effects of aerobic exercise on cocaine self-administration: Importance of exercise output. Poster presentation at the 19th annual Faculty for Undergraduate Neuroscience Satellite Event at the Society for Neuroscience: Washington, DC

PROFESSIONAL ACTIVITY AND SERVICE

Scientific and Professional Society Service

APA Science Student Council Chair	2016-Present
APA Division 28 Graduate Student Representative	2015-Present
APA Division 28 Undergraduate Scholarship Committee Chair	2015-Present
APA Science Student Council Biopsychology Representative	2015-Present
CPDD Travel Awards Committee Member	2015-Present
International Study Group Investigating Drugs as Reinforcers Webmaster	2014-Present

Department and University Activity and Service

University of Kentucky	
Area Brown Bag Coordinator	2016-Present
Psychology Department Event Planning Committee	2016-Present
Davidson College	
Psi Chi President	2013-2014
Honor Council Representative	2011-2014

Scientific and Professional Society Membership

American Psychological Association, Graduate Student Affiliate	2014-Present
American Psychological Association Division 28, Student Member	2014-Present
American Psychological Association Division 50, Student Member	2014-Present
College on Problems of Drug Dependence, Student Member	2014-Present
International Study Group Investigating Drugs as Reinforcers, Member	2014-Present
Phi Beta Kappa Honor Society	2014-Present
Psi Chi Psychology Honor Society	2012-Present

Mentoring Activity

Marisa Doll, University of Kentucky College of Arts and Science	2015-2016
Michael Romanelli, University of Kentucky College of Medicine	2015-2016
Meredith Doughty, University of Kentucky College of Agriculture	2015

Teaching Activity

Davidson College Teaching Assistant Biology 111-Molecules, Genes, and Cells	2014
Davidson College Head Statistics Teaching Assistant	2012-2014

Ad Hoc Reviewer

Addiction Biology; Biological Psychiatry; Drug and Alcohol Dependence; European Journal of Pharmacology; Experimental and Clinical Psychopharmacology; Journal of Addiction Medicine; Pharmacology, Biochemistry, and Behavior