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Asymmetry of Gains and Losses in Human Decision-Making and Choice: Behavioral Correlates of Loss Aversion, Money, Food, and the Menstrual Cycle

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ABSTRACT

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The purpose of this research is to determine if loss aversion is replicable as an overt behavioral response to potential gains and losses in complex, recurring, uncertain, and risky choice with real gains and losses of money and food. Cognitive methods used to determine the effect of loss have primarily measured verbal response to hypothetical choice scenarios in which participants cognitively predict their behavior in a series of bets or situations involving imagined monetary gains and losses. Less has been done using behavioral methods that measure overt behavioral response to gains and losses of actual commodities. The present study uses the experimental analysis of behavior to measure the asymmetrical effect of loss in multiple choice domains.

A series of four experiments investigated four factors likely to affect the expression and degree of loss aversion: (a) learning and experience with consequences of choice; (b) real gains and losses instead of hypothetical quantities or imagined commodities; (c) gains and losses of a non-quantitative, primary reinforcer (food); and (d) the menstrual cycle. Participants played one of two computer games-in which they earned or lost coins or food tokens exchanged for real food. Participants (N = 27, 15 women) played several 18-minute sessions in gains-only conditions and 16 sessions in 36-minute gains+punishment conditions. Recurring, complex, uncertain, and risky choice was simulated in the games by using 6-ply interdependent concurrent variable interval schedules of reinforcement (gains) and punishment (losses). Choice behavior with real gains and losses of money and food was modeled using the generalized matching law, allowing for the quantification of the effects of potential loss, relative to gains, as a change in bias and sensitivity. Loss aversion was operationalized as gain-loss asymmetry ratios derived from bias estimates produced in unpunished and punished choice conditions.

Gain-loss asymmetry was replicated in both women and men in complex, recurring, uncertain, and risky choice with potential gains and losses of real money and food. Average gain-loss asymmetry ratios were 3 to 6 times greater in choice with money and 4 to 16 times greater in choice with food than those reported in the cognitive and behavioral literature. Although individual differences in response to loss were striking, the asymmetrically larger behavioral effects of loss, relative to gains, were nearly ubiquitous. Marked disruption in sensitivity to reinforcement was observed in punished choice for most participants, but for 33% of participants in choice with money and 42% in choice with food, sensitivity to reinforcers *increased*. No evidence was found for behavioral choice varying with the menstrual cycle.

Keywords: loss aversion, gain-loss asymmetry, hedonic asymmetry, decision-making, choice with money, choice with food, menstrual cycle and behavior, recurring choice, experimental analysis of behavior, generalized matching law, uncertainty in choice, risky choice

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Chapter 1: Economic and Cognitive Models of Human Decision-Making and Choice Behavior

Understanding how individuals choose to allocate behavior to one alternative over another, and in what circumstances they allocate their resources—time, money, physical effort, cognitive resources, social currency, etc.—to one choice alternative over another, is central to understanding human judgment, decision-making, and choice behavior.

> Hardly a minute goes by in our lives when we don't make [choices]. Decisions can be as small as our choices of words or what to have for lunch, and they can be as big as how to plan for retirement or what treatment to choose for a disease. They can balance certainties against risks. They can balance short-term gratification against long-term benefits. They can clearly be right or wrong — but often enough, they involve likelihoods and possibilities that are uncertain, even in the light of all available information. (Wargo, 2011, Introduction para. 1)

Philosophers, both secular and religious, since Plato have tried to explain how and why humans choose the way they do. Because choice almost always involves wealth or resources, the formal study of judgment, decision-making and choice has been dominated by the field of economics for centuries (Wargo, 2011). Although Adam Smith, as early as 1759 (Truzzi, 1966), and economists, such as Irving Fisher and John Maynard Keynes, as recently as the 1940s (Thaler, 2000) stressed psychological factors in decision-making and choice models, the view of humans as rational agents has permeated Western philosophy and the understanding of human choice behavior. In the 1940s, economics underwent a mathematical revolution and depicted humans increasingly as independent, rational, self-interested agents who both optimize and maximize (Hochman & Ariely, 2016; Loewenstein et al., 2014).

Rational Choice Theory and *Homo Economicus*: A Normative Model

Classic economic models of human decision-making and choice are based on a hypothetical, mythical version of humans, the *homo economicus,* or Econ, a theory first promoted by John Stuart Mill, a political economist (Mill, 1836). Econs are understood to be *rational*: they have complete, transitive, and stable preferences irrespective of context; they objectively evaluate all relevant information; and they allocate their behavior and resources between choice alternatives in a way that minimizes costs and pain and that maximizes rewards and pleasure to further their own self-interest (Hochman & Ariely, 2016; Thaler, 2000). Models of decision-making and choice based on the Econ form the basis for rational choice theory (RCT), the theory used by economists to generate hypotheses about decision-making and choice for most of the twentieth century. Rational choice theory provides a framework for attempting to understand and formally model both social and economic behavior (Blume & Easley, 2008; Sen, 2008). Rational choice theory is normative—it predicts how humans (Econs) should behave under the assumption that they are inherently rational.

Choice as a Function of Expected Value

Rational choice theory assumes Econs can optimize and maximize by essentially calculating the expected value of possible outcomes in each choice. The tenets of the theory of expected value were first proposed by Blaise Pascal in 1670—essentially, in order to mitigate uncertainty in outcomes and to maximize benefit, decision-makers should select from all possible outcomes the one with the highest value as a product of its probability (Wargo, 2011).

Choice as a Function of Expected Utility

However, as it became apparent that decision-makers do not consistently perform complicated expected value calculations, either consciously or otherwise, and rarely find themselves with clear-cut choice alternatives, in 1738 Daniel Bernoulli shored up the humans-as-Econs view with the theory of expected utility (Wargo, 2011). Bernoulli demonstrated that decision-makers base choices not on expected values, but rather on the expected utility, or the psychological values, of the choice outcomes (Kahneman, 2003).

An Econ maximizes expected utility (happiness, pleasure, satisfaction, rewards) and minimizes costs (unhappiness, pain, and punishers). The Econ, being aware of all possible options in each choice scenario, will consistently evaluate those options based on stable preferences, maximize their own pleasure, and minimize their pain, and always choose the option that maximizes their expected rewards according to a personal, rather than universal, utility function (Hochman & Ariely, 2016). For example, an Econ's utility function may value not maximization of monetary gains but maximization of social currency by appearing altruistic and unselfish, even at a monetary cost. In essence, if an individual's utility function in a particular decision state can be identified, their behavior will be classified as rational and considered to maximize that utility, and, if choice behavior appears to be irrational, it is simply because the utility function has yet to be identified. For example, within expected utility theory, a decision-maker who over-eats to the point of morbid obesity resulting in heart disease can still be deemed rational because the utility function may value neither short term health nor longevity but the maximization of the immediate pleasures of eating.

The Failure of Rational Choice Theory as a Descriptive and Predictive Model

Even shored up by expected utility theory, RCT cannot adequately account for several irrational, but ubiquitous, features of human decision-making and choice behavior discussed in the following section. And RCT is often not predictive—rationality must be inferred after the behavior occurs and a utility function identified. In cases where a utility function is known *a* *priori*, RCT cannot explain common deviations from rationality wherein individual choice predictably and systematically fails to optimize even within the decision-maker's own utility function (Herrnstein, 1990). Examples are abundant—over-working, under-sleeping, over-eating, over-drinking, over-spending, under-exercising, etc. "The theory of rational choice fails as a description of actual behavior, but it remains unequaled as a normative theory. It tells us how we should behave in order to maximize reinforcement, not how we do behave" (Herrnstein, 1990, p. 356).

Bounded Rationality: A Descriptive Model

Although researchers since Freud have been interested in why people behave the way they do, the formal, scientific study of the cognitive processes involved in decision-making and choice is relatively recent. With the advent of the cognitive revolution in psychological science in the 1950s (Miller, 2003), research methods developed by cognitive psychologists provided a means for analyzing the assumptions of human rationality. Experiments using cognitive methods provide evidence that human decision-makers, unlike Econs, do not predictably behave in ways that reflect the formal statistical and mathematical formulations upon which economic models of behavior are based; instead, they regularly allocate behavior in direct contrast to their own, personal utility functions (Hochman & Ariely, 2016).

In the 1950s, Herbert A. Simon was the first to introduce the concept of *bounded rationality*, an alternative behavioral model to the mathematical modeling of decision-making. The model incorporated the reality that decision-makers had limited cognitive processing capacity and suggested that their minds compensated for those limitations by making outcome predictions based on past experience and learning in the environment and using heuristical cognition, a rule-of-thumb approach to problem solving (Simon, 1955). "Decision-makers, in this view, act as satisficers, seeking a satisfactory solution rather than an optimal one. Therefore, humans do not undertake a full cost-benefit analysis to determine the optimal decision, rather they choose an option that fulfills their adequacy criterion" (Campitelli & Gobet, 2010, p. 36).

Research in cognitive psychology provided a reality-check on the assumptions of human nature by economists. Most famously, two psychologists, Amos Tversky and Daniel Kahneman presented compelling evidence for the sub-optimality of decision-making and choice behavior. Their findings, formalized in prospect theory and discussed in detail later, demonstrated that decision-making, rather than being a rational process, is influenced by the framing of choices and is context-dependent (Kahneman & Tversky, 1979; Loewenstein et al., 2014).

This and similar research nudged the field of economics to modify its homo economicus-based models to reflect decision-making and choice behaviors of homo sapiens more accurately. The subsequent marriage of cognitive psychology and economics resulted in a new subfield—behavioral economics (Hochman & Ariely, 2016). Research in cognitive psychology and behavioral economics has resulted in alternative, descriptive models to account for human decision-making and choice behaviors, models that acknowledge individuals operate within the limitations of bounded rationality. Models based on bounded rationality acknowledge that cognitive biases, mental heuristics, cognitive and temporal processing limitations, and other irrationalities are the norm rather than the exception.

The theory of bounded rationality does not preclude classically defined rational behavior in humans—they intend and act to maximize reinforcement in their own self-interest. In simple choice scenarios where all relevant information needed to optimize returns is known, the possible outcomes have straightforward value differences, and the choice alternatives fall within the same choice domain (as opposed to multiple domains like monetary and social), RCT theory accurately predicts people's behavior. For example, in a simple choice between $100 or $50, a decision-maker is likely to take $100. However, findings that support bounded rationality make it clear that both decision-making and choice behaviors—and the standard of rationality by which to measure those behaviors—are more complex and nuanced than can be accounted for by RCT. Numerous factors that cause human decision-making and choice to deviate from classical rationality models have been identified and are described below.

Features of Choice Affect Decision-Making and Choice Behavior

First, features of choice itself—complexity of the choice, uncertainty of the outcomes, and risk of loss—determine decision-making and choice behaviors.

Complexity of Choice

Decision-making and choice in the real world are frequently complex and rarely simple. Depending on contextual factors, the choice between $100 and $50 may involve decision-making and choice across multiple, interactive choice domains, such as monetary, social, and biologically relevant domains (e.g., reproduction and food). Choice alternatives that reside in multiple domains likely have interacting costs and benefits such as the investment cost of time, energy, and physical or cognitive resources; costs of social reciprocity obligations; costs of social rejection (e.g., for appearing greedy by taking available resources from others, affecting both monetary and social domains); or benefits such as increases in social currency (for appearing unselfish and cooperative).

For example, in the choice between $50 and $100, the $100 option might be associated with costs of time and physical and mental resources spent in physical and cognitive labor while the $50 option, might be associated with benefits of more time available to spend in leisure and engaging with one's social group resulting in increased physical pleasure and increased social currency. Another example is that while saving money and investing may be rational in terms of obtaining larger, later, and long-term rewards of economic security and biological stability, the costs for smaller, sooner, but transitory rewards like unnecessarily expensive clothing, automobiles, and housing, may be perceived to have more short-term utility and function as immediate increases in social standing. Overall, smaller, sooner, short-term, and transitory rewards may be preferred to larger, later, stable, and necessary rewards, demonstrating that even given a utility function, decision-making and choice can be suboptimal when measured at different points. As choice gets more complex, RCT becomes less predictive or usefully descriptive because any choice can be categorized as rational or irrational depending on the utility function applied.

Uncertainty in Choice

Decisions and choice alternatives are rarely accompanied with explicit contingencies and known probabilities of outcomes. More frequently, complex choice is associated with unknown opportunity and unknown rates and schedules of potential outcomes. *Schedule* refers to the interval of time, either fixed or variable, between the delivery of each available outcome. It also refers to the number of responses, either fixed or variable, required to access an available outcome. While some choice involves outcomes on fixed intervals, like a paycheck every two weeks, many outcomes are variable, which indicates that the interval between outcomes, or the number of responses required to access the outcome are varied, unreliable, or unpredictable. For example, the political dynamics of a company, the current job market of a particular field, the volatile general economy, etc., make accessibility and delivery of outcomes unpredictable, and therefore, uncertain. Variable intervals are unpredictable, at least initially until multiple learning experiences with similar choice have occurred. Many choices provide only one opportunity for learning (discrete choice), or opportunities to learn are spaced far apart, making it difficult to determine the relationship between the behavior and the outcome. Additionally, uncertainty about the relative value of possible outcomes results when the outcomes have associated temporal constraints, such as a gain of $50 now or $100 in six weeks. Uncertainty about the likelihood of the payoffs may also result if the two amounts are available in differentially variable installments.

Risky Choice

Complex choice is also characterized by risk—the potential to lose what one already has. In choice with varying levels of potential increases in wealth, the choice that results in the smaller increase may be less enjoyable, but choice that has risk (the potential for invested resources of wealth, time, and energy, etc., to be lost) is likely to be experienced as hedonically painful. Additionally, there may be differential risk associated with potential outcomes if they are available from differentially reliable sources, and so on. Thus, complexity, uncertainty and risk are features of choice that prevent human decision-makers from optimizing in a classically rational way.

Context, Environment, and Situational Factors Affect Decision-Making and Choice Behavior

In addition to features of choice, contextual factors also influence decision-makers' subjective evaluation of potential choice outcomes and opportunities for maximization. Choice is made not only in the context of individuals' self-interest but also in the context of family groups, ideological groups, and groups bound by common laws. Individuals' decisions are influenced by social norms, social expectations, and social constraints (Sunstein, 2005). Rational choice theory assumes that individuals are selfish agents motivated by self-interest, but people's decisions and choices are influenced by a reciprocity instinct (Lea & Webley, 2006); by a desire for cooperation and inclusion; and by the motivations and preferences of others, both within and without immediate social and ideological groups. Often, decision-makers have social causes for which they are willing to donate (lose) money and resources and they sometimes engage in altruistic behaviors, only some of which are rewarded socially or monetarily. And sometimes, as in the case of enforcing perceived fairness in others, social context can even result in self-imposed costs with no clear benefits—the antithesis of rationality (Bar-Gill & Ben-Shahar, 2004; Sunstein, 2005).

The effects of social norms, expectations, and constraints, demonstrate that situational factors—subjective, external influences—rather than an internal, endogenous system of stable preferences and decision-making criteria, affect choice behavior.

Cognitive Limitations Affect Decision-Making and Choice Behavior

In addition to features of choice, context, and situational factors, human decision-makers have cognitive limitations that affect their expression and degree of rationality.

Absence of Constant, Well-Defined Preferences

Rational choice models assume that preferences are not impacted by factors that are irrelevant to the choice/task at hand. However, research suggests that preferences are subjective and affected by emotional states, situational factors, and assessment of utility judged relative to external reference levels rather than a consistent endogenous preference system resulting in inconsistent preferences and even preference reversal (Kahneman, 2003).

Temporal Discounting

An influential cognitive limitation that results in preference inconsistency or reversal is the almost ubiquitous tendency to over-value imminent consequences of choice (rewards and punishers) over distant consequences, a phenomenon called temporal discounting (Ainslie &

Haslam, 1992; Green et al., 1994; Mazur & Herrnstein, 1988; Rachlin & Green, 1972; Rachlin et al., 1991). *Discounting* refers to the devaluation of available rewards or punishers as a function of time before their delivery with imminent consequences having more weight than distant ones. Temporal proximity of the consequences of choice as well as the temporal proximity of the choice itself can influence preference. For example, $50 now may be preferred over $100 in two weeks, but if the choice is between $50 in 50 weeks or $100 in 52 weeks, waiting two weeks for the additional $50 will be preferred (Herrnstein, 1990). Temporal constraints on outcomes not only affect their subjective value, but proximate consequences also influence the perceived certainty of available rewards and punishers while distant consequences are susceptible to disruption and therefore, perceived as less certain resulting in decreased weighting (Herrnstein, 1990).

Heuristical Cognition

Additionally, humans don't, or can't, optimally process information in complex choice, as strict rationality requires. Instead, they use heuristics—mental rules of thumb or mental shortcuts that facilitate decision-making with minimal time and effort (Kahneman, 2003). For example, using the availability heuristic, people tend to rely more heavily on irrelevant but easily accessible information than on information that is essential for optimizing rewards and minimizing costs in the task at hand.

Cognitive Biases

In addition to heuristical cognition, cognitive processing of decision-makers is limited by cognitive biases—systematic errors in information processing that frequently result in non-optimization. Cognitive biases occur when individuals attend only to quickly or easily accessible situational features or rely on subjective evaluations of those features, influenced by familiarity, affect, or hedonic preference, rather than objectively evaluating all available, salient information (Kahneman, 2003). Cognitive biases result in preferences based on situational or subjective qualities of the alternatives rather than the features that are directly relevant to maximizing rewards and minimizing costs.

For example, the in-group bias refers to the tendency to believe or support someone within one's own social group over an outsider, disregarding other available information, thus removing objectivity from decisions and choices that involve others (Knobloch-Westerwick et al., 2020). Another example is the fundamental attribution bias, sometimes called the fundamental attribution error. This bias is the tendency to attribute negative behavior of others to internal, intractable character traits and to ignore external environmental influences and constraints while doing the exact opposite when attributing the causes of one's own negative behavior and attributing the reverse in both situations when assessing causes of positive behavior. This bias persists even when individuals are explicitly informed about the environmental constraints of others (Jones & Harris, 1967). Yet another bias is the anchoring bias—information that is presented first is weighted more heavily than subsequent information and subsequent information is assessed relative to the anchor rather than objectively (Kahneman, 2003).

Hundreds of cognitive biases have been identified and confirmed by reproducible research (Thomas, 2018). They can affect all aspects of human decision-making including "belief formation, reasoning processes, business and economic decisions, and human behavior in general" ("Cognitive Biases," 2021, para. 5). A cognitive bias might be the result of something as simple as an individual's preference for choice alternatives presented in a certain text color or presented on a certain side that matches handedness (Nisbett & Wilson, 1977). In contrast, an

Econ's decision-making and choice behavior would not be affected by information irrelevant to optimizing rewards and minimizing costs or to the arrangement or presentation of that information.

Framing Effects

Limitations on cognitive processing are also influenced by the type of information, its accessibility, it's characteristics or attributes, the order in which it is presented, or the context of in which it is encountered—known as the framing effect (Bless et al., 1998). Individuals tend to make different choices from the same information if the information is presented in terms of positive or negative possible outcomes, i.e., gains or losses, or rewards or punishers. *Gain* and *loss* are defined as the possible outcomes of choice alternatives—money earned or lost, social opportunity gained or lost, lives saved or lost, group membership status gained or lost, and so on.

For example, in a well-studied thought-experiment introduced by Kahneman and Tversky (1981), participants responded to a hypothetical problem wherein they chose between treatment plans to deal with an impending outbreak of a deadly virus. When participants were given the option between Treatment A that "saves 200 lives," or Treatment B with, "a 33% chance of saving all 600 people and a 66% probability of saving no one," 72% of participants choose Treatment A, the positively framed treatment. However, when participants were given the options between Treatment A in which, "400 people will die," and Treatment B with "a 33% chance that no people will die and a 66% probability that all 600 will die," only 22% chose Treatment A, the negatively framed treatment (Kahneman & Tversky, 1981, p. 453). Note that in all scenarios, the expected value of both treatments is 200 lives saved and 400 lives lost. The preference reversal resulting from framing in terms of gains rather than losses illustrates that framing affects both cognitive processing abilities and the calculations of utility—not rational behavior in which an Econ would engage.

Reference Dependency and Affective Influences

The framing effect illustrates just one situation in which decision-makers do not simply derive the expected value of potential gains and losses by the predicted, net final wealth states, nor do they rely strictly on predictions of expected utility—200 lives saved should have the same psychological value regardless of framing. Instead, the perception and subsequent evaluation of potential gains and losses appears to be dependent on a decision-maker's initial wealth state (a personal reference point) and utility lies in gains or losses relative to that point (change) rather than absolute wealth outcomes (Kahneman, 2003). For example, the expected utility of a choice of a 50% chance to win $100 and a 50% chance to lose $50 may be evaluated differently by a person who is unemployed and has only $100 than by a person with stable employment who has $1000.

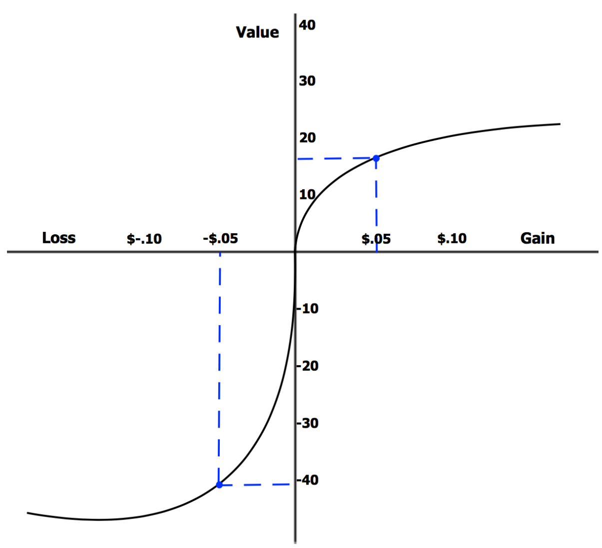
When assessing potential gains and losses from an initial wealth state, decision-makers have affective responses to the gains and losses, which can obfuscate the expected value of alternatives. As mentioned previously, in choice alternatives with varying levels of potential gain, the alternative that results in the smaller gain may be less enjoyable, but risky choice with the potential for loss, is experienced as pain. Losses have a greater psychological and emotional effect on choice behavior than gains of the same absolute value, that is, there is hedonic asymmetry associated with gains and losses (Kahneman & Tversky, 1979).

Prospect Theory and Loss Aversion: Keystones for Explaining Bounded Rationality

Hedonic asymmetry was first identified by Daniel Kahneman and Amos Tversky (1979). They formalized two phenomena: (a) reference dependence, wherein decision-makers derive expected utility of possible outcomes by evaluating changes in wealth relative to a subjective, initial reference point rather than evaluating absolute, final wealth states, and (b) hedonic asymmetry, wherein decision-makers have higher levels of affective response to losses compared to gains because they weight the value of losses more heavily than gains (Kahneman & Tversky, 1979). Prospect theory predicts a value function for potential gains and losses that accounts for several choice behaviors that appear to deviate from strict rationality. The value function (see Figure 1) includes three distinctive features: (a) "It is concave in the domain of gains, favoring risk aversion; (b) it is convex in the domain of losses favoring risk seeking; (c) most important, the function is sharply kinked at the reference point and *loss averse*—steeper for losses than for gains *by a factor of about 2–2.5"* (Kahneman, 2003, p. 705; see also Kahneman, et al., 1991; Kahneman & Tversky, 1979; Tversky & Kahneman, 1992).

Figure 1

Example of Value Function for Gains and Losses in Prospect Theory



Note. Reprinted from Loss Aversion. (2021, June 15). In *Wikipedia*. https://en.wikipedia.org/wiki/Loss_aversion

A central tenet of prospect theory critical to the refutation of rational choice models is that hedonic asymmetry and its associated value function of gains and losses result in loss aversion—the tendency for decision-makers to avoid losses rather than to pursue gains when allocating behavior between choice alternatives. Loss aversion may contribute to several choice behaviors that demonstrate bounded rationality, such as the endowment effect and the status quo bias (Kahneman, et al., 1991; Kahneman, 2000), but perhaps the most striking deviation from rationality is that potential losses are hedonically more unpleasant, painful, or distressing than potential gains are enticing (Kahneman, 2003). The implications are evident both at the level of the individual and the group—while incurring losses is never preferred, the fear of incurring losses prevents decision-makers from taking even well-calculated risks with potential for higher returns or implementing innovative, albeit risky, solutions ("Why Do We Buy Insurance," 2021).

Loss aversion is a particularly useful behavior to study when attempting to understand decision-making and choice because it demonstrates several features and contributing factors of bounded rationality: bias; effects of complex choice involving uncertainty and risk; hedonic asymmetry and the effects of emotion; preference reversal; and framing effects.

First, loss aversion may result in the non-optimization of available rewards because they are ignored to avoid costs. As mentioned previously, the tendency to focus on some information, or some attribute of information, while ignoring other relevant information that may help to maximize rewards, is the essence of cognitive bias. For example, in a choice scenario in which one choice alternative is associated with possible losses and possible gains, and another choice alternative is associated only with gains, the effects of hedonic asymmetry will drive the allocation of choice behavior away from the alternative with losses, regardless of the quantity and quality of possible gains in that option. In choice where the losses result in a net loss, this could easily be explained by RCT. However, in choices where there would be a net gain, despite some loss, bounded rationality is manifest.

Second, loss aversion is frequently the result of complex choice—choice that involves multiple, sometimes interacting choice domains in uncertain and risky conditions. Risky choice has outcomes that include potential loss—and loss aversion results in risk aversion in the domain of gains and risk seeking in the domain of losses. If choice outcomes are uncertain (the relevant contingencies, probabilities and frequency of potential gains and losses are unpredictable) risk aversion or risk seeking will emerge as a function of domain.

Third, loss aversion is essentially an emotional response that interferes with maximization and therefore, rationality. Decision-makers do attempt to maximize their gains when allocating behavior between choice alternatives and they do assess utility of potential outcomes based on the expected happiness, pleasure, and satisfaction associated with rewards (gains) and the expected unhappiness and pain associated with punishers (losses). However, the asymmetric and heavier emotional weight attributed to losses (Kermer et al., 2006) results in loss aversion, which interferes with maximization and efforts to assess utility.

Fourth, loss aversion demonstrates decision-makers' tendency for inconsistent preferences and preference reversal in response to uncertainty and risk. The differential hedonic value placed on gains and losses means that, to mitigate uncertainty, decision-makers will become risk-averse in the domain of certain gains and uncertain losses, preferring sure gains, but become risk-seeking in the domain of uncertain gains and certain losses, preferring uncertain gains.

And fifth, if choice alternatives involve cognitive or affective forecasting about the expected utility of possible but uncertain gains and losses, then framing in terms of losses, rather than gains, will elicit loss aversion and determine if choice behavior is risk-avoidant or risk-seeking. Although RCT predicts that the goal of any decision-maker is to maximize value, utility, or rewards while minimizing costs to attain a certain goal state, framing effects demonstrate that when information is presented as possible losses, certainty and the avoidance of risk is preferred over utility maximization.

Thus, the measurement of loss aversion behavior could reasonably be used as a proxy for measuring deviations from rationality, or, in other words, the degree of bounded rationality human decision-makers exhibit under certain conditions. This study will systematically and precisely measure the degree of loss averse behavior produced by decision-makers in complex, risky and uncertain choice and investigate several factors that may influence its expression.

Summary of Concepts in Bounded Rationality Relevant to This Study

Humans appear not to allocate behavior and resources between choice alternatives to consistently minimize costs and pain while maximizing rewards and pleasure in furtherance of self-interest as predicted by normative models based on RCT. Instead, research in cognitive psychology and behavioral economics have provided empirically based descriptive models of decision and choice behavior that demonstrate bounded rationality. Human decision-makers' ability to optimize is constrained by (a) the features of choice, including complexity, uncertainty, and risk; (b) the context, environment, and situational factors in which decisions are made; and (c) decision-makers' own cognitive limitations, including absence of constant, well-defined preferences, tendency toward temporal discounting, use of mental heuristics and resulting cognitive biases, and susceptibility to framing effects, reference dependency, and asymmetrical hedonic influences. Prospect theory formalizes two phenomena that contribute to rationally bounded behavior: (a) reference dependence, wherein decision-makers derive expected utility of possible outcomes by evaluating changes in wealth states relative to a subjective, initial reference point rather than evaluating absolute, final wealth states, and (b) hedonic asymmetry, wherein decision-makers have greater affective response to losses compared to gains because losses are weighted more heavily than gains. Prospect theory predicts a value function for potential gains and losses that (a) is concave in the domain of gains promoting risk aversion; (b) is convex in the domain of losses promoting risk seeking; and (c) has an inflexion point at individuals' reference point promoting loss aversion: the asymmetrical valuation of losses, relative to gains by a factor of 2—2.5.

Chapter 2: Behavioral Models that May Contribute to Bounded Rationality in Human Decision-Making and Choice

The tendency to view behavior through the lens of rationality criteria, which prescribe how idealized humans should behave rather than describing how real humans behave, has created a sort of false standard for and untenable definition of rationality and optimization. The classical understanding and associated criteria for rationality may have acted as a red herring for understanding human decision-making and choice and, therefore, also as a barrier for understanding processes that contribute to rationally bounded decision-making and choice behaviors. The abundant evidence for bounded rationality requires some inquiry into why humans do not consistently make choices that maximize gains and minimize losses. It also calls into question the utility of the classic understanding of rationality. Accordingly, the following sections discuss two theoretical paradigms that shed light on processes that may contribute to rationally bounded decision-making and choice behaviors. The possibility that bounded rationality may be satisfactory, or even optimal, given cognitive limitations, the influence of the past and local environments, and the effects of learning, is also discussed.

Evolutionary Psychology Model of Decision-Making and Choice Behavior

Evolutionary psychology models assume that mental and psychological traits of the mind are adaptations—the products of natural selection in response to environmental pressures. This perspective, also known as functionalism, assumes that highly typical species characteristics, like underlying mechanisms of systematic and predictable decision-making and choice behaviors, must have had some adaptive value (Powell et al., 2016). Some developmental, cognitive, and evolutionary psychologists argue that bounded rationality and cognitive biases, including loss aversion, may be viewed as adaptive when observed contextually in the larger environment (Haselton et al., 2016).

Natural Selection

Researchers who have challenged the ability of RCT to either describe or explain choice behavior have suggested that natural selection is the process and standard by which rationality should be defined, not individual behavior in discrete choice conditions (Frank, 2003; Herrnstein, 1990; Margolis, 1987). The principle of natural selection is that organisms capable of adapting to pressures in the environment have higher chances of reproductive success than those less capable, making adaptive characteristics more prevalent in subsequent generations (Darwin, 2009, p. 225). Adaptive characteristics such as mind mechanisms for solving problems in the environment, e.g., behavioral "rules of thumb," may appear to be suboptimal at the level of individual choice, but at a global level of recurring choice may approach or achieve optimization (Herrnstein, 1990, p. 358; see also Heiner, 1983; Houston & McNamara, 1988).

The criteria for optimization may be better identified at the level of several choice sequences bundled together (a global analysis) and assessed for overall rewards available in the complex environment rather than at the level of discrete/single choice (a local analysis).

Satisficing versus Maximization: An Alternative Perspective.

In RCT, optimization is synonymous with maximization—that is, maximizing rewards, gains, and pleasure, while minimizing punishers, losses, and pain, is the most effective use of decision-making resources. However, given the bounded rationality of human decision-makers and the complex choice environments in which they must choose, criteria for optimization must be more nuanced. That is, the interacting factors of choice complexity, cognitive limitations, and the pressures of a complex and dynamic environment in which one must survive, must be included in any meaningful criteria used for assessing optimality in choice.

Although individual choices may look irrational when assessed with the criteria of RCT, they may be optimal, overall, because they are adaptive (lead to reproductive success) in the larger environment in which the choices occur (Herrnstein, 1990). From a global perspective, it may be that individual choices need only be satisfactory, or good enough, and maximization is not necessary to be either adaptive or optimal. For example, cognitive scientists have identified two mind-systems, System 1 and System 2, that facilitate decision-making and choice behavior (Evans & Stanovich, 2013; Stanovich & West, 2000). System 1 is fast, intuitive, effortless, and mostly subconscious. It employs biased and heuristical thinking and saves time, effort, and resources, and, for purposes of survival, it satisfices, despite its lack of maximization capability. System 2 is a conscious process, it is slow, effortful, methodical, and requires complex analysis and reasoning (Kahneman, 2003). This system is more capable of global analysis of choice and arranging local choice environments to maximize series of choice rather than single choices (Ainslie, 2005). This system can be willfully employed if it becomes apparent that System 1 is not capable of satisficing (Kahneman, 2003). In RCT, only System 2 would be considered rational, but the availability of the two systems makes an overall, global, optimization plausible.

The evolutionary psychology model of choice behavior assumes that human social and cognitive instincts—like reciprocity and enforcing fairness, and the use of heuristics and biases—currently exist because they were adaptive and satisfactory in past environments. Heuristical and biased cognition can save time, effort, and cognitive resources when making decisions and can work well, on average, across individual choices and between choice domains, despite the probability that the same patterns of cognition will not result in maximization at the level of individual choices.

For example, loss aversion, though not rational in the classical sense of optimization, could be considered both adaptive and optimal in a dynamic, complex choice environment. Risk aversion and a bias away from potential loss rather than pursuing potential gains may not maximize rewards in one choice domain but may facilitate more time, energy and resources being available in another competing domain. A pregnant female, or one caring for offspring, may exhibit loss aversion and prefer to avoid losses of food rather than pursue gains if avoiding losses conserves energy and provides opportunity for escaping a mortal threat. Likewise, losses of money or food can mean death for self or offspring and at that point, parallel gains, or even excessive gains, are irrelevant. Thus, it is possible that decisions deemed to suboptimal at a local level of analysis can be deemed optimal at the global level and optimality in decision making and choice may be sex or gender specific.

In other words, assessing overall patterns of behavior in complex and interacting domains and investigating their fitness, not only in the environment in which they were selected but also in the environment in which they are observed, is likely to be more useful in determining optimality than assessing individuals' behaviors in isolation and in comparison to the standards of the mythical Econ.

Concepts in Evolutionary Psychology Model Relevant to This Study

Evolutionary psychology models that utilize the concepts of biological substrates of behavior and environmental effects on expression of behavior may explain, at least partially, rationally bounded behavior that deviates from classic notions of rationality. Patterns of rationally bounded response behavior (a) may be distinctive to intra-species groups (gender and sex) who are optimizing differential choice alternatives with their associated consequences, which may appear irrational when compared to a homogenous normative standard; (b) may be adaptive to and satisfactory in the particular, possibly gendered, environments in which decisions are made; and (c) may be optimal, overall, when decisions are made across multiple, interacting choice domains. The first item in the list will be directly investigated in this study while the latter two items provide rationales for the need to investigate loss aversion, a rationally bounded behavior, and are discussed in depth in Chapter 3.

Operant Learning Model of Decision-Making and Choice Behavior

Evolutionary psychology models are not the only possible, or even, necessarily, the most likely, contributing factors for explaining the mechanisms underlying behavioral response to risky and uncertain choice alternatives. Behavioral repertoires, the full range of behaviors a person is capable of emitting in response to the environment (American Psychological Association, n.d.), are acquired through processes of experience and learning from the consequences of choice available in a particular environment (operant learning). Nor are evolutionary psychology models the only, or necessarily the most important, factors that explain possible gender differences in behavioral response patterns. Because women and men face distinct pressures in the current environment, any differences in patterns of decision-making and choice behavior in conditions of risk and uncertain probable gains and losses between women and men may be the result of learned behavioral repertoires shaped (selected) in their current environment.

Behavioral psychology is the branch of psychology that utilizes operant learning models, focuses on directly observable and measurable behavior, and uses the experimental analysis of behavior (EAB) (Powell et al., 2016). As originally defined by Watson (1913), EAB is "a purely objective experimental branch of natural science. Its theoretical goal is the prediction and control of behavior" (Watson, 1913, p. 248). Observable behavior falls into three categories (a) innate behavior developed via evolutionary process of natural selection; (b) respondent behavior elicited by either neutral or conditioned antecedent environmental stimuli; and (c) behavior that occurs as a function of consequences available in the local environment—operant behaviors (Moore, 2016). Most human behavior is operant behavior—behavior that has become increasingly probable, or improbable, as a function of its consequences. This section focuses on the third category, operant behavior, which is under direct investigation in the present study.

Operant learning models of decision-making and choice make no assumptions about rationality, optimization of some utility function, or even cognitive processes of bounded rationality. Instead, these models assume that patterns of behavior will be selected at the level of the individual through processes of reinforcement and punishment in accordance with pressures from the local environment in which decisions and choices are made. In this way, behavior response patterns, or repertoires, are adaptive and can be viewed as a sort of reflection of the pressures (consequences) that are available in and characterize the local environment. The normative focus of behavioral models is not on rationality, as in RCT, but on the interactive effects of three factors (a) the individual—the organism's innate and reflexive behavior, genetic capabilities, and individual variability, (b) the individual's behavioral repertoire—the organism's behavioral response palette developed through previous experience and classical and operant conditioning, and (c) environmental control—the choice alternatives available in the current environment with their associated reinforcing or punishing consequences (Powell et al., 2016).

Understanding the third factor, environmental control, is critical for understanding all behavior, including decision-making and choice behavior under conditions of risk and uncertainty, the behaviors that are under investigation in the present study.

Environmental Control of Decision-Making and Choice Behavior via Reinforcement and Punishment: Response Selection and Behavioral Repertoire Development

In a single choice scenario, a response results in a consequence that either increases or decreases the probability of a similar response occurring again in similar circumstances. After repeated exposure and learning from the consequences in any particular response class, predictable and stable response patterns emerge. To the extent that the environment in which decision-makers operate is stable, stable patterns of behavior across choice scenarios (behavioral repertoires) will emerge. Environmental control of behavior can be viewed as three integrated processes that result in a behavioral repertoire that is reflective of the unique environment in which behaviors occur: reinforcement and punishment; the three-term contingency of reinforcement; and behavioral selection.

Reinforcement and Punishment. When an individual emits a response, the probability of the response being repeated under similar circumstances in the future increases when it is followed by a reinforcing, or strengthening, consequence. Likewise, the probability of the response being repeated in similar circumstances decreases if it is followed by a punishing consequence. Operant behaviors are determined by their reinforcing or punishing consequences (Powell et al., 2016), rather than by expected value, expected utility, or a cohesive and stable set of rational, cognitive preferences that result in maximization.

Three-term Contingency of Reinforcement. In the experimental analysis of behavior, "the relation between (a) the circumstances in which behavior occurs, (b) the behavior itself, and (c) the consequences of the behavior is called the three-term contingency of reinforcement" (Moore, 2016, p. 91). A contingency can be formally described as:

$$S^{D} : R \rightarrow S^{R+} \tag{1}$$

where S^{D} is a discriminative stimulus that "sets the occasion" for a response (i.e., signals that a consequence for a response is available) (Moore, 2016, p. 91). R is behavior (i.e., the response emitted in the presence of the stimulus) and acts as an operant on the environment to produce the consequence. The response produces S^{R+}, a consequence which, in turn, acts as a stimulus affecting the probability of the response recurring in the future (Moore, 2016). In this case, the S^{R+} is a positive reinforcer, but it could also be a negative reinforcer or a positive or negative punishment: S^{R-}, S^{P+}, or S^{P-}, respectively. This contingency is the unit of analysis for operant behavior (Moore, 2016).

Behavioral Selection. Behavior comes under the control of the environment in the sense that behavioral responses are selected according to their adaptivity in the circumstances in which they occur. Operant learning functions similarly to natural selection: "Reinforcing consequences select responses that satisfy the contingencies in an organism's environment; that is, those responses occur more often in the future" (Moore, 2016, p. 92), while behaviors that do not result in reinforcing consequences or result in punishing consequences are less likely to be repeated. And, whereas natural selection occurs at the level of the species, behavioral selection occurs at the level of the individual and can be viewed as a type of "mini-evolution" in which an organism's adaptive behaviors increase in frequency and become part of the individual's learned behavioral patterns (repertoire) while non-adaptive behaviors decrease in (Powell et al., 2016, p. 216). Observed behavioral patterns have been selected for through a process of operant learning and are a sort of reflection of the environment and its available reinforcers (potential gains) and punishers (potential losses).

It is important here to note three things. First, the use of the term *adaptive* in selection processes does not indicate *optimal* in the sense of maximizing a utility function, nor does it indicate a value judgment of desirable or appropriate behavior. It simply indicates that the environment exerts its distinctive pressures in the form of reinforcement and punishment and behaviors that are reinforced or punished will adapt to that environment.

Second, although the evolution of behavioral patterns occurs at the level of the individual, features of the local physical environment are not uniformly reinforcing or punishing across individuals—the environment interacts with the individuals' differences and their previous learning. As mentioned earlier, sex and gender are two examples of individual differences that interact with differentially available reinforcers and punishers and subsequently result in differential adaptive behavioral repertoires.

And third, although behavior is selected at the level of the individual, behavioral patterns and learning are transmitted both within groups socially and between generations (Moore, 2016).

Individual Differences in Operant Learning Models: Sex and Gender

Individual differences play a key role in all three determinants of behavior mentioned previously: (a) the individual, (b) the individual's behavioral repertoire, and (c) environmental control.

In the first determinant of behavior, individual differences are constrained by the genetic and physiological variability found within a species. In the case of intra-species groups, sex differences and their effects on response behavior, the differentially available reinforcers and punishers in the environment between sexes, and the subsequent selection of behavior should not be underestimated. The relevance of sex differences in operant learning models is discussed extensively in Chapter 3, particularly in the discussions on the need to specifically study behavior in women and in the tend-and-befriend stress-response example.

In the second determinant of behavior, gender differences play a large role in the development of individuals' behavioral repertoires. Gender differences determine the degree and nature of access to decision-making and choice opportunities (decision classes) with their associated reinforcements (gains) and punishers (losses). This determinant is also discussed extensively in Chapter 3 in the discussions on the need to investigate decision-making and choice behavior in women, the effects of gendered environments and sex exclusion in research, and the resulting myths about women that affect access to decision-making domains.

The degree and kind of the third determinant of behavior, environmental control, is partially determined by sex and gender differences that interact with and affect the development of environmental choice domains. For example, access to education, socio-economic status, geography, socio-cultural norms and roles, leadership and decision-making opportunities in government, religion, education, public health, and politics, are a few of the environmental factors that frequently interact with sex and gender to provide differential contingencies of reinforcement and therefore, differential patterns of environmental control.

Adaptivity Versus Rationality in Operant Learning Models

In the discussion on RCT in Chapter 1, rationality was defined in terms of maximization, among other things. Chapter 3 includes a discussion of "the myth of the irrational female" (King, 2020, p. 287) and of the lay and common understanding of the term *rational* that means reasonable or understandable behavior according to a set of expectations, desires, or societal norms. However, as mentioned at the beginning of this section, operant learning models make no assumptions about either usage of the rationality term. Instead, operant learning models assume that behavior adapts to environmental pressures and describe and predict behavior according to an analysis of selection by consequences of three-term contingencies. According to this view, environmental control and adaptivity are the determinants of behavior rather than rational choice and maximization or lay understandings of rationality. These normative prescriptions are relevant to human decision-making and choice behavior only to the extent that the environment reinforces behaviors that conform to those normative standards. Otherwise, they are just wishful, or in some cases harmful, thinking (see Chapter 3).

Allocation of Behavior Between Choice Alternatives in Operant Learning ModelsDecision-making and choice behavior can be broadly defined as the allocation of behavior by an individual between available choice alternatives at a particular time in a particular environment. Any decision or choice can be conceptualized as the allocation of behavior between just two alternatives—one alternative and another alternative, or one alternative and all other possible alternatives "bundled" together. Also, choice must necessarily occur between alternatives that differ in some way; the consequences of alternatives must be in competition otherwise, no alternative exists to consider. Competing alternatives may have differential rates of reinforcement (gains) and punishment (losses), differential probabilities of receiving those consequences, and differential costs (e.g., in the form of time, energy, physical resources) required to access those consequences. Finally, it is only reasonable to discuss decisions and choices as the option to allocate behavior between two concurrently available alternatives. This is true even if one of the alternatives is to reserve allocation of behavior until a future time. Thus, decision-making and choice can be narrowly defined as the allocation of behavior between two competing and concurrent alternatives.

Matching, Melioration, and Optimization

The way in which many species, including humans, allocate their behavior between concurrent choice alternatives is a function of the reinforcers obtained in each of the alternatives. Specifically, decision-makers, because of operant learning in recurring choice, will proportionately allocate their responses to match the proportion of obtained reinforcers in the choice alternatives, a process called matching (Herrnstein & Prelec, 1991; Powell et al., 2016).

The behavioral requirements (costs), frequency, delay, and interval between delivery of the reinforcers in each alternative, also known as the schedule of reinforcement, determine decision-makers' allocation of responses, with richer alternatives receiving proportionately more responses than leaner alternatives. Richer reinforcement schedules have a higher frequency of reinforcement, proximate versus delayed reinforcers, and relatively fewer costs.

Costs are a function of both the number of responses required to access a reinforcer and how much time must pass before a response results in another reinforcer. Examples of reinforcers being dependent on response numbers include sales quotas in which a specific number of sales must occur to receive an agreed upon wage—this is a fixed ratio reinforcement schedule (FR). Or a potential sexual partner is required to emit a variable number of commitment-assuring responses before gaining access to romantic rewards. Because the required number of responses varies from romantic episode to episode, it is known as a variable ratio reinforcement schedule (VR). Examples of reinforcers being dependent on time elapsed before a response will result in a reinforcer include an employee who must work eight hours each workday for two weeks and after the final hour on the last day, they receive a paycheck—this is a fixed interval reinforcement schedule (FI). Or, a potential sexual partner is required to spend a minimum, variable amount of time "getting to know" and "communicating" before a commitment-assuring response will be rewarded with romantic rewards. Because the required amount of time spent communicating varies between romantic episodes, it is known as a variable interval reinforcement schedule (VI).

Matching happens via melioration—according to melioration theory, allocation of a behavior shifts toward choice alternatives that have higher value, or, in other words, higher local rates of reinforcement. “Shifting will cease at the point that the two alternatives have about equal value in terms of costs (responses made) and benefits (earned reinforcers),” or, at the point of matching (Herrnstein, 1990, p. 362).

At a superficial level, it appears that matching via melioration validates the optimization requirement of RCT—choice alternatives with the richest reinforcement schedules will receive proportionately more of an individual’s responses, which, in turn, seems likely to result in maximization of one’s overall level of reinforcement (Powell, et al. 2016). However, melioration does not necessarily facilitate optimization (Herrnstein & Heyman, 1979). “The problem is that this tendency to move toward the higher valued alternative can sometimes result in a substantial reduction in the total amount of reinforcement obtained” (Powell, et al., 2016, p. 385). Overall optimal reinforcement requires an allocation of behavior between choice alternatives that takes advantage of the reinforcement schedules in *both* alternatives rather than just shifting behavior towards the alternative with the “higher value regardless of the long-term effect on the overall amount of reinforcement” (Powell, et al., 2016, p. 383; see also Herrnstein, 1990; Herrnstein & Heyman, 1979).

The Matching Law

The matching law describes “a direct proportionality between rate of responding and rate of reinforcement” (Poling et al., 2011, p. 313). Under concurrent schedules of reinforcement, the relationship of the allocation of behavior (responses) between choice alternatives and the consequences received for those responses can be described formally and mathematically as follows:

$$\frac{R_1}{R_1+R_2} = \frac{S_1^{\mathrm{R}}}{S_1^{\mathrm{R}}+S_2^{\mathrm{R}}} \tag{2}$$

where R_1 "is behavior (i.e., total responses) allocated to Alternative 1, [R_2] is behavior allocated to Alternative 2, [$S^{R}{}_1$] is the number of reinforcers received [i.e., stimuli that affect the future probability of the responses recurring] under Alternative 1, and [$S^{R}{}_2$] is the number of reinforcers received under Alternative 2" (Poling, et al., 2011; p. 314; Powell et al., 2016, p. 376). Although the notation used in references to the matching law are not consistent among authors, the behavior, or responses, are always displayed on the left side of the equation and the consequences that determine the probability of future response are always displayed on the right side of the equation. For the sake of clarity and ease of remembering, going forward, the following notation will be used throughout this study:

$$\frac{B_1}{B_1+B_2} = \frac{R_1}{R_1+R_2} \tag{2a}$$

where B_1 is the behavior (total responses) allocated to choice alternative 1, B_2 is behavior allocated to alternative two, R_1 is the number of obtained reinforcers in alternative one, and R_2 is the number of obtained reinforcers in alternative two (Poling et al., 2011).

The matching law is particularly relevant when understanding choice behavior in conditions of uncertainty (probability of choice outcomes is unknown), and before repeated exposure, experience, and operant learning has resulted in behavioral stability. Recall "that on VI schedules, reinforcers become available at unpredictable points in time (and any responses before that point will not result in reinforcement)," and given the unpredictability, it might be assumed that individuals would distribute their responses randomly between the alternatives "hoping to catch the reinforcers on each alternative as they become available" (Powell et al., 2016, p. 375). However, it has been experimentally demonstrated that the response distributions are actually systematic and result in behavior that can be quantified by the matching law (Baum, 1979; Poling, et al., 2011; Powell et al. 2016).

However, in complex choice in concurrent responding, choice behavior as a function of reinforcement frequently deviates from matching in three predictable and systematic ways.

Deviations from Matching and the Generalized Matching LawPredictable, systematic deviations from matching include undermatching, overmatching, and bias. Undermatching is a "systematic deviation from the matching relation, for preferences toward both alternatives, in the direction of indifference" (Baum, 1974, p. 232), and results in fewer responses being allocated to the richer schedule than that predicted by matching (Powell, et al., 2016). For example, little-to-no cost for switching between choice alternatives is one circumstance in which undermatching occurs (Powell et al., 2016). Costs of switching responses from one choice alternative to another can take the form of time, effort, energy, or resources and, although behavior will continue to be governed by its consequences, their effect on future behavior can be strengthened or weakened by switching costs.

In overmatching, "the proportion of responses on the richer schedule versus the poorer schedule is *more* different than would be predicted by matching" (Powell et al., 2016, p. 380). Overmatching can occur when high switching costs result in increasingly infrequent switching between choice alternatives and disproportionately more responses being allocated to the richer alternative (Baum, 1974; Powell et al., 2016; Rasmussen & Newland, 2008).

In biased responding, a higher proportion of behavior is allocated to one alternative regardless of whether that alternative contains the richer or poorer schedule of reinforcement. Bias may result from factors associated with learning and experience (Rasmussen & Newland, 2008), features of the choice architecture like physical location of alternatives or cognitive framing (Thaler & Sunstein, 2021), or hedonic preference for one reinforcer over another (Miller, 1976). The extent to which decision-makers prefer one alternative over the other, regardless of the rate of reinforcement, is bias.

The deviations from matching were formalized and incorporated into the matching law after Staddon (1968), and Baum and Rachlin (1969) observed that the graphical depictions of the matching law (Equation 2) failed to “display the regularities” in their response data (Baum, 1974, p. 231). However, when the data were formulated as behavioral response ratios as a function of obtained reinforcer ratios, rather than proportions (see Equation 3), “the order in the data became readily apparent” (Baum, 1974, p. 231).

$$\frac{B_1}{B_2} = \frac{R_1}{R_2} \tag{3}$$

In Equation 3, B_1 and B_2 are behaviors (responses) allocated to alternative 1 and 2, respectively, and R_1 and R_2 are reinforcers (stimuli that affect future probability of the recurrence of B) obtained from alternatives 1 and 2, respectively. If a line is fitted to the data using Equation 3 by graphing the logarithm of the response ratio B_1/B_2 as a function of the logarithm of the reinforcement ratio R_1/R_2, the line is defined as follows:

$$\log\left(\frac{B_1}{B_2}\right) = s\log\left(\frac{R_1}{R_2}\right) + \log b \tag{4}$$

where s, the slope, and log b, the y-intercept, are free parameters derived empirically (Baum, 1974). Poling, et al. (2011) explain that logarithmic transforms are useful because they, “shorten the number line needed to portray a set of observations and often transform functions that are curvilinear when the raw data are portrayed into linear functions, which are easier to describe and to remember" (p. 317). Equation 4 is known as the *generalized matching relation* and can be used to describe behavior (across multiple species and in multiple decision-making domains) as a function of its consequences and systematic deviations from matching. The notations for s and b are inconsistent across the literature and are sometimes referred to as a and c, a and k, or c and k, respectively (Baum, 1979; Poling et al., 2011; Rasmussen & Newland, 2008). For simplicity and clarity this study uses s and b to indicate sensitivity and bias, respectively.

Undermatching and overmatching indicate the degree of sensitivity to the available reinforcement ratio between choice alternatives. Sensitivity is the extent to which response ratios correlate with obtained reinforcer ratios, and is represented by the slope (s), in Equation 4 (Baum, 1974; Poling et al., 2011; Rasmussen & Newland, 2008). If $s = 1$, a change in the reinforcer ratio results in an equal change in the response ratio and indicates strict matching. If $s < 1$, then the response ratio changes less than the reinforcement ratio indicating that the behavior is less sensitive to reinforcement and undermatching is the result. If $s > 1$, there is a greater change in response ratios than in reinforcement ratios indicating heightened sensitivity to reinforcement and overmatching is the result (Rasmussen & Newland, 2008).

Bias, or preference for one alternative over another regardless of the rate of reinforcement, is represented when log $b \neq 0$ (Baum, 1974). If log $b = 0$, no behavioral bias is evident. If log $b > 0$, there is a bias toward the numerator (choice alternative 1) and if log $b < 0$ there is a bias toward the denominator (choice alternative 2) (Rasmussen & Newland, 2008). See Equation 4. Recall from the discussion on bounded rationality that human decision-makers make reference-dependent valuations of the utility of choice outcomes—gains and losses away from a personal reference point (Kahneman, 2003). Recall further that loss aversion is a hedonic preference to avoid losses rather than pursuing gains, regardless of available reinforcers between the choice alternatives. In other words, loss aversion, is a bias in both the cognitive and behavioral uses of the term.

Summary of Operant Learning Models of Decision-Making and Choice Relevant to This Study

Operant learning models not only provide explanations for rationally bounded decision and choice behavior, but also describe conditions and learning processes wherein patterns of decision and choice behavior are acquired.

Operant learning models assume that patterns of behavior are the result of (a) individuals' innate capabilities, and (b) individuals' behavioral repertoires (acquired through past learning) interacting with (c) current environmental conditions/pressures in the form of reinforcing or punishing consequences. Via a process of selection, consequences result in the strengthening (increased probability of recurrence) of some responses and weakening of others.

Sex and gender differences in behavioral repertoires may exist due to the inherent effects of sex and gender in all three determinants of behavior—innate capabilities, some of which are related to reproduction; differentiated behavioral repertoires developed in gendered environments; and differentially available consequences of choice between women and men.

Behavioral models make no assumptions about rationality and optimization as defined by RCT but assume behavior is adaptive and will conform to environmental pressures of reinforcement and punishment. Rather than maximizing, decision-makers allocate their behavior proportionately to reinforcements available between choice alternatives. Through the melioration process, decision-makers continue to distribute behavior in the direction of the alternative with the highest local rate of reinforcement until a sort of equilibrium of costs and benefits is achieved, a process which does not always result in maximization of the overall rate of reinforcement across choice alternatives.

Deviations from matching include undermatching and overmatching (sensitivity), and bias. In a series of choice with concurrent variable-interval schedules of reinforcement, an individual’s response behavior, as a function of its consequences, along with their sensitivity to reinforcement and tendency toward bias can be described mathematically using the generalized matching law. This study explicitly uses an operant learning model of choice and the experimental analysis of behavior to investigate behavioral bias in complex choice (conditions of risk and uncertainty) across sex and gender. Behavioral bias is interpreted as loss aversion and operationalized by using the bias parameter in the generalized matching law to quantify the degree of loss aversion towards unpunished alternatives, regardless of rates of reinforcement.

Chapter 3: On the Need to Investigate Decision-Making and Choice Behavior in Women and to Collect Sex-Disaggregated Data

Women, at just over half of the population, represent an intra-species group that has experienced, and continues to experience, distinctive environmental pressures. Many of these pressures are directly related to reproduction and caring for offspring—the costs of reproduction for women are high and unique relative to those for men. Other environmental pressures are socio-cultural, but many, if not most, of these are related, at least indirectly, to reproductive costs. Effects of past environmental influences that shape decision-making and choice behavior mechanisms (biological substrates of behavior) and effects of current environmental influences that influence the expression of those mechanisms should be directly and specifically investigated in women.

Historical and Contemporary Environmental Influences on Women's Decision-Making and Choice Behavior

Historically, and currently, choice alternatives available to women are unique in quality, risk, costs, and benefits. Western, educated, industrialized, rich, and democratic (WEIRD) countries (Henrich, et al., 2010) have highly gendered socio-cultural and socio-economic environments that affect the types and features of choice alternatives available to women. Although women in most countries throughout the world share many of the same types of and constraints on decision problems, the present study investigates decision-making and choice behaviors, specifically, loss aversion, only with women in the United States.

Gendered Environments Delimit Choice Alternatives for Women

First, gendered roles mean that women tend to disproportionately be the main providers of child-care, domestic labor, and aging parent care (Craig, 2006). This means that women are over-represented in supportive, care-taking roles and under-represented in authority, leadership, decision-making, and policy-making roles in government, the justice system, business and industry, religion, public health, education, and even domestic life. Men are over-represented in all areas of research (Schwab et al., 2017). Accordingly, social influences not only shape and prepare women and men for their respective decision-making roles and related social and economic opportunities, but also result in the institutionalization of associated risks, costs, and benefits, making specific decision alternatives being differentially available and viable. Given that men are overrepresented in decision-making and policy-making positions in all areas of society, the choice architectures designed and influenced by men naturally reflect cost-benefit packages that will most likely (a) benefit the men framing the choices, and (b) reflect the types of decision-making mechanisms used by men.

Gendered Environments Require Differential Navigation of Choice Alternatives by Women and Men

Second, the prevalence of male-dominated authority, leadership, decision-making and policy-making roles means that men and women must navigate the socio-cultural and socio-economic decision-making environments differentially. In other words, decision-making and choice behavior, particularly behavior related to potential gains and losses, is likely to vary with gender. For example, in the workplace, the disparity in the proportion of men to women predicts sexual harassment, a cost that women experience disproportionately (McDonald, 2012).

In another example, cultures with decision-making entities dominated by men are more likely to provide reduced-cost decision-making spaces for male-typical behaviors and characteristics like physical aggression. This, combined with gendered roles that emphasize female sexuality, may contribute to women experiencing sexual violence and assault at disproportionately high rates. Relatedly, justice systems in these types of environments are not equipped to handle complaints of women which can exacerbate or minimize costs for behavior, depending on gender (Becker, 1999).

Yet another relevant example is that to attain comparable levels of authority, leadership, and decision-making prowess in a male-centric social and economic environment, women are often expected to exhibit male-typical social behaviors but are socially punished when they do—this is called the "double bind" (Debebe, 2017, p. 1).

A final example of the need to differentially assess costs and benefits in the socio-cultural and socio-economic environments is that choice opportunities that may yield the highest benefits are often perceived by women to be unavailable due to social constraints or, are unavailable due to institutionalized constraints. Careers in STEM often yield direct access to wealth stability. However, social influences that emphasize sexuality, sexual desirability, and reproductive roles for girls mean that many girls lose interest in STEM-related education around puberty onset. In studies where social sexual-related traits are minimized, i.e., in all-girl schools and in cultures where STEM fields are socially acceptable for women, girls' interest in STEM education persists (Dasgupta & Stout, 2014).

Gendered Environments Create and Enforce Differential Costs and Access to Resources) for Women

Third, gendered societies create and enforce differential access to all types of resources, the gains and losses of which are a central feature in decision-making and choice. Differential access to resources between the sexes has been the case in education, citizenship and voting rights, property ownership rights, control over one's own property and earnings, and divorce and child-custody rights.

For example, universal suffrage for women in the United States was not achieved until 1920, about 150 years after white, propertied males (Edwards, 2002). Until the mid-19th century, children were legally considered the property of the father in cases of divorce (“Divorce and custody,” n.d.). Although the percentage of women enrolled in higher education surpassed that of men in the late 1970s, women with degrees that lead to the highest paying jobs, and positions of leadership, authority, and resource allocation are still under-represented relative to men (Gould et al., n.d.; Harrison et al., 2021). In a famous case, Ruth Bader Ginsburg, the late Supreme Court Justice (1933-2020), was one of nine women in a class of 500, admitted to Harvard Law School. After graduating at the top of her class from Columbia Law School in 1960, she was denied employment by several firms, including a Supreme Court clerkship, based on her gender (Block, 2020).

In education, citizenship and voting rights, property ownership rights, control over one’s own property and earnings, and divorce and child-custody rights, women’s access to the associated resources came decades and centuries later than for their male counterparts and was dependent on geography and socio-cultural context. The result is that costs and benefits in these decision domains are more inconsistent, uncertain, and unpredictable for women compared to men.

Also, asymmetry in access to resources persists. Gendered access to resources is differentially costly to women and beneficial to men in the types of jobs available. For example, in the United States, the ratio of men to women in executive jobs and STEM is 10: 1; and at comparable levels of education, overall women earn only 82% of men’s wages while in the 95th percentile of earners they earn only 74% of men’s wages (Gould et al., n.d.).

Additionally, because women have relatively high costs associated with reproduction, access to technology to control one's own reproduction is crucial in mitigating costs and benefits but is often limited by social, ideological, and religious constraints and lack of access to health care.

In summary, the associated risks, costs, and benefits of choice alternatives that are available and unique to the current environment affect behavioral expression. Both historically and currently, choice alternatives available to women are unique in quality, risk, costs, and benefits. Because the types of choices and their associated costs and benefits that women experience are unique, not only is it likely that distinctive behavioral response types exist, but also women will need to optimize on different features of choice alternatives than their male counterparts, i.e., optimization in choice may look different for women compared to men and compared to measures of the general population that rely on aggregated, averages of behavior across sex and gender.

Evolutionary Environmental Influences on Women's Decision-Making and Choice Behavior

In addition to recent historical and current environmental conditions that can affect the expression of behavior in women, it is assumed that the biological and physiological substrates of behavioral patterns and responses that led to successful survival and reproduction in the evolutionary past have been passed on to subsequent generations through principles of natural selection. Given the differential cost of reproduction and the differential parental investment of females in caring for and protecting offspring, it is plausible that biological behavioral substrates related to reproduction and to survival—threat response, perception, and response to risk—are distinctive in women. Women, specifically, face unique environmental pressures that may shape expressions of behavior. Critically, an understanding of *human* decision-making and choice requires the explicit study of these phenomena in women. Unfortunately, there has been a massive failure to do so.

Failure to Investigate Women's Behavior and Associated Biological Substrates

Until recently, there has been an almost universal failure in the scientific literature to consider effects of both the evolutionary-past environment (biology, physiology, neuroendocrinology, etc.) and the recent and current environment (psychology, behavior) on decision-making and choice behavior in women, specifically. This failure is the result of not only a long-held belief in homo economicus (the rational *man*) but also a lack of explicit research into female psychology, behavior, biology, pharmacology, and physiology. Sex exclusion of females in all areas of scientific research was ubiquitous in all but the last decade of the 20^{th} century (Beery & Zucker, 2011; Holdcroft, 2007; Liu & Dipietro Mager, 2016; Low et al., 1994; Vidaver et al., 2000). Unfortunately, many findings from research conducted prior to 1990 continue as the standard for informing our understanding of human behavior, psychology, health, and physiology.

Sex Exclusion in Behavioral Research: Psychology and Behavior

Erroneous assumptions and myths about the rationality and decision-making and choice behavior of women are a result of sex exclusion in psychological and behavioral research. Many early and influential studies that continue to inform our understanding of human nature and that continue to populate psychology textbooks relied on male-only subject samples. To name a few, Festinger and Carlsmith's (1959) study on forced compliance and cognitive dissonance; Milgram's (1963) experiments on authority and social influence; Asch's (1955) conformity experiments; Sherif's et al. (1954) robbers cave experiment on between-group competition and cooperation; and Schachter and Singer's (1962) experiment on physical arousal and emotion.

An analysis of the proportion of women subjects in research published in the *American Journal of Psychiatry*, the *Journal of Consulting and Clinical Psychology*, and the *New England Journal of Medicine* reported that in 1982, only 33% of participants were women (Low et al., 1994). Additionally, studies that investigate women specifically have historically received less funding. For example, in 1987, just 12.5% of the NIH's budget of 6.2 billion was spent on studies specific to women's physical or mental health (Low et al., 1994).

In the last three decades, the inclusion of women in research has improved. In 1985 a report by the Public Health Service Task Force on Women's Health led to the establishment of NIH policy mandating inclusion of women in clinical research (NIH Office of Research on Women's Health, 1990) and in 1986 the NIH created the Office of Women's Health to improve research specific to women and required all grant proposals to include women unless they provided a scientific rationale for single-sex design (NIH Office of Research on Women's Health, 1990). Although sex inclusion improved, a review of 50 NIH grant proposals found that 20% provided no information on the sex of participant samples, about 33% indicated that both sexes would be included but did not specify the proportions, and proposals for studies involving only male subjects provided no rationale for their single-sex design (Nadel, 1990). By 1991 representation of females as research subjects in some areas, like mental and addictive disorders, increased (NIH Office of Research on Women's Health, 1990).

Historically, rationales for excluding females from psychological and behavioral research include (a) the assumption that male subjects adequately represent the whole population (Low et al., 1994); (b) undesirable variability in subjects' responses caused by hormonal fluctuation

(Low, et al., 1994), (c) limited financial and other resources for larger subject pools, and (d) lack of interest in questions related to sex differences (Prescott, 1978).

Sex Exclusion in Research on Behavior-related Biology: Biology, Pharmacology, and Physiology

Erroneous assumptions and myths about the rationality and decision-making and choice behavior of women are also a result of sex exclusion in biological, pharmacological, and physiological research. Some of the most egregious patterns of failing to explicitly study women occur in these fields. The result has been misconceptions, misdiagnoses, and erroneous assumptions about women's response behavior.

Biology Research. In 2009, Beery & Zucker conducted a meta-review of sex-bias in research in ten biological disciplines and found male bias in eight. Neuroscience had the most egregious male bias—just 28% of 800 studies included female subjects (Beery & Zucker, 2011). In addition, "studies that included both sexes failed to analyze results by sex" (Beery & Zucker, 2011, p. 565).

"Male bias stems from the misconception that female animals increase experimental variability due to cyclical fluctuating hormones and the historical belief that no major differences exist between the sexes outside of reproductive functions" (Woitowich et al., 2020, p. 1; see also Institute of Medicine, 2001). Interestingly, this exact rationale was cited for excluding females in a study on EEG and behavioral correlates of loss aversion that was being conducted in the research lab in which the author of this paper worked in 2014. Due to the complexity of controlling for effects of hormonal fluctuations on EEG measures, women were not being included. This was the inspiration for the current study of behavioral measures of loss aversion in women.

Common rationales for male-centric research practice in biology research are similar to the rationales for sex-exclusion in behavioral research: (a) cyclical hormonal fluctuations make females intrinsically more variable, and therefore “too troublesome for routine inclusion” in biological research, and (b) descriptions of sample size by sex in the absence of a sex-based analysis are unimportant (Beery & Zucker, 2011, p. 565). Sex-disproportionate samples may be used intentionally to produce more robust findings—many researchers reported that they excluded women to minimize experimental variability rather than for a scientific rationale (Woitowich et al., 2020).

In 2014 the NIH announced new rules, effective 2016, that required sex to be included as a biological variable in research proposals. In 2019, a replication of the 2009 Beery & Zucker study reviewed nine biological disciplines across 34 journals and found a significant increase in the proportion of studies that included both sexes in their subject pools, but at least 20% of reviewed studies still excluded women (Woitowich et al., 2020). So, although the explicit study an inclusion of women in biology research is improving, in eight of the nine disciplines, there was no increase in the proportion of studies that included sex-based analyses and one-third of the studies that included both sexes failed to quantify sample size by sex, precluding replication (Woitowich et al., 2020).

Pharmacological Research. Current knowledge in pharmacology is still plagued by the effects of sex exclusion in large-scale NIH-sponsored studies conducted decades ago: the Multiple Risk-Factor Intervention Trial used 15,000 men in its subject pool (Stamler & Neaton, 2008); the Physician’s Health Study that investigated the prophylactic effect of aspirin in cardiovascular disease used 22,071 men (Steering Committee of the Physicians' Health Study Research Group, 1989); and large studies on aging and health, caffeine and heart disease, AIDS drugs (Long, 1993), and obesity (Dresser, 1992) have used all-male samples. All NIH-sponsored large-scale trials of cholesterol-lowering drugs included only male subjects (Cotton, 1990). "Cardiovascular disease has only recently been discovered to be misdiagnosed and mistreated in women despite it being a leading cause of death in women in the U.S. Cardiac therapies and prophylactics, such as aspirin, have been designed for and tested on male samples" (Low et al., 1994, p. 82).

A NIH General Accounting Office internal report (1990) identified several problematic research practices: failure to factor sex differences into prescription drug testing; one-fourth of drug manufacturers deliberately do not recruit sex-representative samples in drug trials; when included as research subjects, women were underrepresented; inadequate numbers of women were included to detect sex-differences related to drug-response; and when women are included in drug trials, the trial data are rarely analyzed to determine if women's response to drugs differ from men's (General Accounting Office, 1992).

The over-reliance on male subjects in drug trials and aggregate measures of females and males not only obscure key sex differences in clinical studies but also are harmful because women experience higher rates of adverse drug reactions than men (NIH Office of Research on Women's Health, 1990). The U.S. Government Accountability Office (2001) published findings that 80% of drugs taken off market for adverse effects were removed for incorrect dosage sizes and related harmful effects to women.

In 1994, the NIH mandated that all drug trials had to include females. However, sex inclusion in pharmacological research trended dismally downward from 33% of studies using both sexes in 2009 to 29% in 2019 and increased the male to female ratio of participants from 5.1:1 to 5.8:1 in that same period (Woitowich et al., 2020). This is incredible.

Rationales for sex exclusion in pharmacological research include (a) simplification of experimental design and labor-saving practices by using the "most homogenous population possible … middle-aged white men" (Cotton, 1990, p. 1049); (b) unnecessary noise in the data caused by cyclical hormonal fluctuations, the analysis of which wouldn't yield "any new or important information" (Low, et al., 1994, p. 81); (c) potentially adverse effects on child bearing capacity despite intention, age, or desire of research subjects to give birth (Low et al., 1994); and as Vineet Arora, Assistant Dean of Scholarship and Discovery at University of Chicago's Pritzker School of Medicine said, (d) "male senior investigators are still overrepresented as principle investigators and may not have sex inclusion on their radar" (Cooney, 2020, para. 5), that is, they are unaware of the problem or don't care.

Physiological Research. Sex exclusion in research has ramifications in our understanding of physiologically related behaviors. For example, sex differences in stress responses related to cravings has implications in the science of addiction (NIH Office of Research on Women's Health, 1990). Successfully assessing risk and the associated costs and benefits of allocating resources between choice alternatives is crucial for survival and thriving. Females and males not only experience different types of threats but also different access to resources, both endogenous and exogenous, to respond to threat. For example, "human females have much to fear from human males, including rape, assault, homicide, and abuse of offspring … Thus, evolved mechanisms of female survival likely protected against a broad array of threats, including those from males of their own species" (Taylor et al., 2000, p. 418).

In 1994, after the NIH began requiring inclusion of female participants in all clinical trials and physiological research, sex inclusion in physiological behavioral research improved. (Beery & Zucker, 2011; Woitowich et al., 2020). Somewhat. In a review of 200 studies on physiological and neuroendocrine response to stress in over 14,000 research subjects, Taylor et al. (2000) reported that prior to 1995 women made up only 17% of subjects and by 2000 the proportion of women increased to 35%. The historical level of sex-exclusion indicates a knowledge gap in sex-specific physiological and neuroendocrine research. See Taylor et al. (2000) for a comprehensive review of the literature on animal and human neuroendocrine response to stress, in which the typical understanding of the human stress response is found to be incomplete and male specific.

In their essential work for understanding sex-differences in behavioral responding to stress (threat as well as decision under conditions of uncertainty and risk), Taylor et al. (2000), present compelling evidence for a female-specific stress response in which *tending,* "nurturant activities designed to protect the self and offspring that promote safety and reduce distress" (p. 211), and *befriending,* "creation and maintenance of social networks" that facilitate tending processes (p. 211), are female-typical responses to many types of stress. They provide evidence for the profiles and mechanisms of sex-specific physiological and neuroendocrine processes that differentially mediate the primary stress response. They also describe the resulting context-dependent and sex-specific behavioral expressions of response to stress.

A few key points from Taylor et al. (2000) relevant to this study are repeated here: (a) although, the primary physiological mechanisms may be similar in females and males, the stress response in women is not well characterized by the "fight-or-flight" metaphor (p. 411; see also Panksepp et al., 1999); (b) the original research on the fight-or-flight response and most subsequent research "exploring its parameters has been conducted on males, especially on male rats" (p. 412); (c) aggression in response to stress occurs reliably in both females and males but under different types of threat conditions and is mediated by distinct physiological mechanisms and environmental contexts (see also Adams, 1992; Allen et al., 1993; Brain et al., 1992; Bjorkqvist & Niemela, 1992; Eagly & Steffen, 1986; Sandnabba, 1992; Stoney et al., 1987; Stoney et al., 1988); (d) although "the physical fight response is the most robust area of aggression that shows higher lever for males than females in rodents, primates and humans" (p. 414), one of the most robust gender differences in research on adult human behavior is that under conditions of stress, women tend to affiliate with others, particularly other women, significantly more than men (see also Holmstrom, 1992); (e) "female-typical responses to stress and the biobehavioral mechanism that underlies the tend-and-befriend pattern may build on attachment caregiving processes that downregulate the sympathetic and hypothalamic-pituitary-adrenocortical (HPA) responses to stress," resulting in a response that more closely resembles a tend-and-befriend response rather than fight-or-flight (p. 411; see also Klein et al., 1998; Uvnas-Moberg et al., 1993); and (f) "neuroendocrine evidence from animal and human studies suggest that oxytocin, in conjunction with female reproductive hormones and endogenous opioid peptide mechanisms," are responsible for the female-typical response (p. 411; see also Windle et al., 1997).

Taylor's et al. (2000) research demonstrates that female-typical response behavior to stress and threat and their decision-making and choice behavior under conditions of risk and uncertainty are not well characterized by the male-typical responses that have been identified and assumed to be universal. It also demonstrates the scientific poverty of sex-exclusionary practices in behavioral research; the need to investigate decision and choice behavior under conditions of risk and uncertain in women explicitly ; the deleterious effects of excluding females from research because of cyclical hormonal fluctuations; the importance of experimental design that facilitates collecting and reporting sex-disaggregated data; and given historical sex-exclusion in research, the field of human decision making and choice still has potential for novel and important discoveries.

The historical rationale for exclusion of females in stress studies has been the same as the historical rationale for exclusion of females from biology and clinical drug trials—researchers claim that, “because females have greater cyclical variation in neuroendocrine responses (due to reproductive cycles), their data present a confusing and often uninterpretable pattern of results” (Taylor et al., 2000, p. 412).

In summary, the current lack of understanding of female rationality in decision-making and choice is a result sex exclusion in psychological, behavioral, biological, pharmacological, and physiological research in contexts of male-centric social, cultural, and socio-economic environments. In all areas of research, women have been excluded due to a common rationale—assumption of inexplicable variability in data due to monthly hormonal fluctuations associated with the menstrual cycle. Women, who make up over slightly half of the human population, have consistently been excluded from behavior-relevant research for the very thing that distinguishes them—their sex.

Historical and Contemporary Assumptions Regarding Rationality and Decision-Making and Choice Behaviors in Women

Across the social sciences (especially economics, logic, systems science, and computer science), researchers use “*game theory*: mathematical models of strategic interaction between decision-makers” (“Game Theory,” 2021, Introduction para. 1) to study the effects of choices made by rational decision-makers attempting to maximize their utility preferences (Ross, 2019). In game theory, the efficacy of players’ strategies and the degree of rationality (reward maximization and cost minimization) they employ can be accurately assessed only when players are assumed to be playing the same game with the same rules. Previous sections highlight the many ways in which women, by necessity, “play” unique decision-making and choice “games,” often with different rules, than their male counterparts. The result is that the identification of criteria necessary for accurately describing, predicting, and assessing women’s decision and choice behavior has not occurred. Instead, a common practice has been to assess women’s behavior with criteria unique to male-centric decision and choice architectures. Accordingly, in male-centric, gendered socio-cultural and socio-economic environments, beliefs about female rationality, judgment, and decision-making and choice capabilities and behaviors are often based in myth, folklore, and gender roles that demand “proper,” or desired behavior of females, rather than empiricism. Female sex exclusion in behavioral research has resulted in erroneous assumptions and myths about rationality and the effects of the female menstrual cycle on decision-making and choice.

Women and Rational Choice: Myths, Folklore, and the Menstrual Cycle

Rationality is commonly equated with formal logic and objectivity, domains which have socially and historically been associated with masculinity (Oliver, 1991). “One common and persistent sexist, historical assumption, can be described as ‘the myth of the irrational female.’ It is the idea that women are *pathologically* emotional, and thus have a reduced capacity for reason, due to their reproductive biology” (King, 2020, p. 287; see also Ussher, 2011). Before patterns of bounded rationality were formally identified, it was common to characterize females as irrational while males were presumed to follow the homo economicus model. This is likely the result of not only sex exclusion in research but also historical gendered roles and expectations of appropriate and acceptable female behavior (King, 2020). Ironically, according to empirical research in bounded rationality, all humans behave irrationally (at least in the classical sense) in response to complex, uncertain and risky decision-making and choice and are heavily influenced by affective, psychological aspects of potential outcomes.

For a comprehensive review of the historical timeline and the development of the social myth of emotional "irrationality" connected to the menstrual cycle, see King (2020). A few of the essential factors and issues contributing to the myth are repeated here.

First, physical symptoms of the menstrual cycle, e.g., fatigue, water retention, muscular tension, menstrual bleeding pain, heavy bleeding, lower back pain, and migraine, have been known and treated for 3800 years (King, 1998). Through the 1500's, female-specific symptoms were still characterized as primarily physical, but from the 17^{th} century, symptoms increasingly became categorized as emotional and psychological (King, 1998). Influential physicians from the 1600's-1900's facilitated the philosophical change from menstruation as a physical phenomenon to a psychological pathology: Thomas Sydenham (1624-1689) re-classified the Greek term *hysteria* from a gynecological condition to a "female-prevalent nervous condition caused by a weaker nervous constitution and subsequent emotional instability" (King, 2020, p. 288; see also Gilman et al. 1993); Sigmund Freud promoted the concept of hysteria as a psychological neurosis (King, 2020; see also Freud & Breuer, 2004); Sir Almroth Wright (1912), a well-known physiologist and ant-suffragist publicly claimed as a fact that women's minds were inferior as a result of their monthly "physiological emergencies" (King 2020, p. 289; see also Wright, 1912); and in 1931, a U.S. gynecologist, Robert T. Frank, influenced the classification of menstrual symptoms as a medical condition in which the main characteristic was "nervous tension" (King, 2020, p. 289, see also Frank, 1931). Unfortunately, Frank's descriptions of the symptoms of nervous tension were "value judgments on contemporary views of improper or undesired female behavior: 'hysterical woman,' 'husband to be pitied,' 'unbearable,' 'shrew,' or 'impossible to live with'" (King, 2020, p. 289, see also Frank, 1931). These men's interpretation of hysteria and menstrual symptoms were in line with "pre-existing philosophical assumptions that women were inherently physically, spiritually, and intellectually inferior to men, which justified men's dominant social position and facilitated the origin of the belief that *undesirable* female behavior was linked to the distinguishing features of femaleness" (King, 2020, p. 288), the womb and its associated menstrual cycle.

Second, in the Diagnostic and Statistical of Mental Disorders (DSM) the symptoms of menstruation have predominantly been codified as mood-based, rather than physical, further stigmatizing premenstrual symptoms as a psychological disorder (Reid, 2017). In its current version DSM-5 TR (American Psychiatric Association, 2022), only one of 11 Cluster B and C symptoms are explicitly physical, and six are explicitly mood-based or psychological. Despite physical symptoms being the most prevalent and most disruptive of menstrual changes for most women, all systematic reviews of clinical trials of premenstrual symptoms use mood-based criteria suggesting confirmation bias, priming effects of tracking tools based on the DSM criteria for premenstrual dysphoric disorder, and culturally bound notions of sex-related health (King 2020).

And third, symptoms of menstruation appear to be bound culturally. The subjective experience of menstrual symptoms is influenced by "cultural beliefs and practices" rather than medical facts that are universally experienced or diagnosed, and cultural conditioning shapes "which variations in mood and physical sensations are noticed and cause concern" (King, 2020, p. 295; see also Chrisler et al., 2012).

The view that females have inferior rationality and reasoning capacity due to menstrual effects is still prevalent and continues to damage women. In 2009 when Sonia Sotomayor was appointed to the Supreme Court of the United States, a popular talk show host, G. Gordon Liddy said, “Let’s hope that the key conferences aren’t when she’s menstruating or something, or just before she’s going to menstruate. That would really be bad. Lord knows what we would get then” (National Organization for Women, 2009, para. 3).

Damaging Effects of the Myth of Irrationality and the Menstrual CycleUnintentional or otherwise, pathologizing of the menstrual cycle and the perception that the menstrual cycle contributes to irrationality, stigmatizes women, hinders their access to decision-making and leadership positions and, subsequently, access to the associated resources.

For example, the Reykjavík Index (Harrison et al., 2021), a global measure used to identify areas of society in which prejudice exists, annually assesses attitudes toward women and men in the G7 countries (Canada, France, Germany, Italy, Japan, the UK and the U.S.), as well as India, Kenya and Nigeria, in terms of their capacity for leadership. In its most recent survey of more than 20,000 adults, only 61% to 84% view women as equally capable decision-makers and leaders as men (Harrison et al., 2021). In measures that mask social desirability effects and in which participants are unaware that their unconscious bias is being measured, 45% of Americans agree that men are superior leaders (Setzler, 2019).

Accordingly, globally, women are paid less and are much less likely to be in senior positions. Despite evidence that women in senior management of the banking and finance sector is associated with more stability and higher financial returns—this sector remains imbalanced in terms of gender and 40% of people worldwide think men make better business executives (Beck et al., 2013; Sahay & Cihak, 2018). Additionally, about half of the world’s men and women feel that men make better political leaders (Rivera, 2020). In 2019, the number of female heads of government was ten of 193 countries, down from 15 of 193 countries in 2014 (Rivera, 2020).

Summary of The Need to Investigate Decision-Making and Choice Behavior in Women

In summary, empirical research into possible effects of the menstrual cycle on women's decision-making and choice behavior is crucial to understanding human decision-making and choice behavior more completely and to clear up harmful assumptions and myths associated with women's behavior. Given differential evolutionary environmental pressures between the sexes, it is plausible that a biological behavioral substrate that facilitates optimization of chances for reproduction and survival of self and offspring has been selected for and is, at least indirectly, influenced by the menstrual cycle, as illustrated in the tend-and-befriend stress response. Presumably, related behavioral capacities would manifest in response to decision-making and choice scenarios that are directly relevant to reproduction and survival of self and offspring and that feature risk, uncertain outcomes of probable benefits (gains) and perceived costs (losses). Given differential pressures in the current environment between the sexes, it is unclear if menstrual cycle-mediated behavior would manifest only in response to decisions and choice directly related to reproduction and threat or to risky and uncertain choice in general.

Chapter 4: Scholarly Contributions & Rationale of Study

Loss aversion is a particularly useful cognitive bias and behavioral phenomenon to study when attempting to understand decision-making and choice because it demonstrates several well-known features of bounded rationality: reference dependence; the effects of emotion on decision-making; heuristical thinking and cognitive bias; effects of uncertainty and risk; preference reversal (contextual intransigence); and framing effects (see Chapter 1). Four scholarly contributions of this study are: (a) the conceptualization of loss aversion as a behavioral phenomenon rather than as a latent mental variable; (b) the simulation of non-hypothetical complex choice (with tangible money and food); (c) the application of the EAB and small-*N* methodology to decision-making and choice research; and (d) four factors that may affect the expression and degree of loss aversion as an overt, behavioral response.

Conceptualization of Loss Aversion as an Overt Behavioral Phenomenon

There seems to be a lack of consistency and clarity in the literature about how to characterize loss aversion. As Mukherjee (Mukherjee, 2019) notes, there is some controversy and logical circularity in the literature—the results of both conceptualizing loss aversion as a psychological principle or a cognitive process to explain cognitive phenomena such as status quo bias, sunk cost fallacies, and endowment effects (Kahneman et al., 1991; Kahneman, 2003; Mukherjee, 2019), and also using those same phenomena to provide empirical evidence for loss aversion as a phenomenon. “For example, loss aversion was quoted as an explanation for endowment effect but at other times, endowment effect was quoted as a phenomenon that provided empirical evidence for loss aversion” (Mukherjee, 2019, p. 2; see also Camerer, 2005; Thaler, 1980). While loss aversion is commonly understood to be a cognitive bias, many operationalization methods and their associated measures have done little in the way of clarifying the issue beyond that. Two factors likely contribute to the confusion. One, loss aversion is commonly conceptualized as a latent mental variable (a bias in the sense of some internal quality of rationality or irrationality that one possesses). Two, a large portion of the measures used to investigate loss aversion rely on verbal reports of perceptively accessible cognitions associated with loss averse response to hypothetical choice scenarios (this despite the common assumption that biased cognition operates imperceptibly).

Regarding the debate of how to characterize loss aversion, this study aims to provide supporting evidence that loss aversion can be understood as a behavioral phenomenon that develops (is shaped) in response to environmental stimuli in the form of obtained reinforcers and punishers. This study accomplished this by conceptualizing loss aversion as an overt, observable pattern of behavior, rather than as a latent mental variable, thereby making direct measurement possible. The study also avoids the use of verbal reports in responding to hypothetical choice scenarios in favor of direct observation of choice behavior with actual gains and losses.

Loss Aversion as an Overt, Observable Pattern of Behavior Rather Than a Latent Mental Variable

Cognitive psychologists have characterized loss aversion as a hedonic preference (a covert latent mental variable) resulting from a cognitive process. However, because loss aversion defined in this way is not directly observable nor measurable, this study intentionally avoids the identification of loss aversion as a covert latent mental construct. Instead, it assumes that loss aversion is a bias (a preference for allocation of resources away from potential losses rather than in pursuit of gains) resulting from limited cognitive capacities grounded in biological substrates that interact with, and are expressed in, particular environmental contexts (as discussed in Chapters 2 and 3).

The concept of loss aversion as an unobservable, internal quality, trait, or latent mental variable creates problems for valid measurement which may partially explain the lack of clarity regarding how to characterize loss aversion as a principle, process, or phenomenon. De Houwer (2019) explains several difficulties in obtaining valid measurement of latent mental variables: (a) to qualify as a valid measurement, “any measure must be assumed to directly tap into the unobservable” phenomenon and to act as a proxy of it (p. 836); (b) variation in the measurement is hoped to indicate variation in the underlying phenomenon (such as a mental construct like bias) but it is “notoriously difficult to validate this assumption” (p. 836; see also De Houwer et al., 2009); and (c) implicit measures almost always represent more than one mental construct and process making interpretation of the results susceptible to erroneous conclusions.

The difficulty of developing valid measurement for covert latent mental variables may partly explain conflicting findings regarding the expression of loss aversion. Mukherjee (2019) describes some of the conflicting findings—despite the widely held belief in loss aversion as a cognitive processing principle, early studies on the predicted emotional effect of gains versus losses could not replicate loss aversion—when “outcomes were actually experienced, losses did not have as great an emotional impact as predicted” (Mukherjee, 2019, p. 2; see also Kermer et al., 2006; Mellers et al., 1997). In other studies, gains were experienced as equal to or larger than losses for low magnitudes while losses were weighted heavier for high magnitudes of both time and money (Erev et al., 2008; Harinck et al., 2007; Mukherjee et al., 2017; Mukherjee, 2019; Yechiam et al., 2019; Yechiam, 2019). Additionally, some studies investigating phenomena cited as evidence for loss aversion—e.g., status quo bias, endowment effect, risky bet premium, hedonic impact, price elasticity—were not able to confirm loss aversion (Erev et al., 2008; Gal, 2006; Harinck et al., 2007; Morewedge & Giblin, 2015; Mukherjee et al., 2017; Yechiam &

Hochman, 2013; Yechiam et al., 2019). The confusion may be a result of associated difficulties in developing valid implicit measures of covert mental phenomena.

> … In those (frequent) cases in which the measure does not conform with expectations, it is very difficult to determine whether this is due to a problem with the measure (e.g., it does not capture implicit bias adequately) or with the theory about the construct (i.e., ideas about when and how implicit bias influences behavior). (De Houwer, 2019, p. 836)

As an alternative, avoiding implicit measures and using a direct measure of behavior allocation as a function of environmental control will provide an empirical test of loss aversion as a behavioral phenomenon. In this study, loss aversion is operationalized experimentally as the bias parameter from the generalized matching law (see Equation 4) that describes the relationship between the ratio of behavioral responses and the ratio of obtained reinforcers and punishers between choice alternatives. If loss aversion is a behavioral phenomenon, a pattern of behavior allocation away from losses (rather than pursuing gains) that co-varies with available reinforcers and punishers in the environment will be apparent.

Loss Aversion as an Overt, Observable Pattern of Behavior Rather Than a Verbal Report of Covert Events

This study conceptualizes loss aversion as a directly observable behavioral phenomenon and investigate its manifestation with EAB and small-*N* experimental design, a departure from the traditional research methods in bounded rationality. Most of the foundational research conducted on loss aversion utilizes verbal reports (spoken or written) to hypothetical choice scenarios like the following example:

1. Would you accept this gamble?

50% chance to win $150 and 50% chance to lose $100

> *Would your choice change if your overall wealth were lower by $100?*
>
> and,
>
> *2. Which would you choose?*
>
> *(a) Lose $100 with certainty, or*
>
> *(b) 50% chance to win $50 and 50% chance to lose $200*
>
> *Would your choice change if your overall wealth were higher by $100?* (Kahneman, 2003, p. 704; see also Kahneman & Tversky, 1979)

Cognitive prediction, cognitive strategies, education, skill training in probability and statistical assessment, and interpretation influenced by emotion can all influence verbal reports and may explain some of the inconsistent findings. Cognitive and affective forecasting described in verbal reports do not consistently or accurately predict affective, or other behavior (Yechiam et al., 2015). Although verbal behavior is observable and quantifiable, it may change contextually and does not provide a direct measure of private events (covert processes) like biased and heuristical cognition.

It remains unclear how closely verbal reports of responding in hypothetical scenarios mirror allocation of actual resources—e.g., time, effort, wealth—between choice alternatives.

> Describing a set of contingencies in instructions to the subject is no substitute for exposing the subject to the contingencies… Instructions have effects, of course, depending in part on the verbal [learning] history of the subject, but the behavior of a subject to whom an experimenter has explained how a piece of apparatus works will not necessarily resemble one [*sic*] who has come under the control of the terminal contingencies established by that apparatus. (Skinner, 1966, p. 215)

Recall from the discussion on System 1 and System 2 cognitive systems in Chapter 2 that biased and heuristical cognition occurs as an imperceptible, automatic process. Verbal reports are necessarily bound to accessible cognitive processes making them unreliable measures for non-verbal, imperceptible cognitive processes.

Rather than measuring verbal reports of cognitive response to hypothetical gains and losses, this study directly measures overt, behavioral response to actual (non-hypothetical) gains and losses of money and food in complex choice. Additionally, the simulation of complex choice used in this study (discussed in the next section) presents reinforcement contingencies and schedules that are too complex to be assessed via conscious, System 2 processes. Instead, participants are required to learn from experience with the consequences of their behavior allocation between alternatives. This method provides an effective means for measurement of imperceptible, biased decision-making processes, disassociated from verbal fluency, cognitive capability or formal education in statistics and probability assessment, all of which may affect the appearance of rationality in decision-makers and their ability to optimize.

Simulation of Complex Choice in Conditions of Uncertainty and Risk

Choice in real life is rarely simple; that is, choice is rarely between two alternatives with clear benefits disassociated from costs, risk, and uncertainty, such as a simple choice between $50 or $100. More often, choice is complex, and much of the relevant information is initially unknown, like the degree of risk and uncertainty, the contingencies of reinforcement and punishment, the probability and frequency of consequences, and temporal constraints like delay. For example, a complex choice may be 40% probability of $50 immediately after an investment of two hours, some level of effort, and a related but unquantifiable change in social capital or

60% probability of $100 in one week after an investment of three hours, some level of effort, and a related change in social capital.

This study simulates complex choice under conditions of risk and uncertain gains and losses, like the complexity of choice decision-makers experience in non-hypothetical choice. The experimental choice architecture is complex in that it includes a series of up to six sets of recurring choices. Each set contains two concurrent choice alternatives with unique schedules of reinforcement. Risk is introduced when, occasionally, a schedule of punishment is superimposed on the schedule of reinforcement of one alternative in a choice set. Uncertainty is introduced because potential consequences are available on variable interval schedules (VI) of reinforcement and punishment.

The average interval of elapsed time before a response will be reinforced or punished can be calculated if the schedule of reinforcement remains intact over repeated choices. In complex choice, the average interval between available reinforcers is frequently inaccessible to conscious awareness and, therefore, unable to be considered in conscious, deliberative cognition or verbal reports of cognition. For example, in a VI 30-sec schedule, a consequence will be available, on average, every 30 seconds, with the actual interval between available reinforcers varying between one and 60 seconds. The degree of uncertainty varies to the degree that the range of variance in reinforcement intervals makes prediction by conscious cognition unlikely.

Because the choice architecture in this study simulates features of complexity as experienced in every-day choice, in which contingencies, probability and frequency of consequences are initially unknown, the covert, unconscious, cognitive response to consequences is inaccessible. When information about choice features is provided, as is the case in hypothetical choice scenarios, verbal reports (spoken or written) of conscious, but unobservable, cognitive response behavior like cognitive predictions, cognitive strategies, and emotions, are evoked. It remains unclear if verbal reports of cognitive choice processes are analogous to, or accurately predict, overt behavioral allocation of resources between choice alternatives by decision-makers in non-hypothetical decision domains. This study is designed to precisely measure the degree of loss aversion in overt, behavioral responding experienced by decision-makers in complex, non-hypothetical choice. The choice architecture in this study is sufficiently complex that many features of choice (contingencies, probability, and frequency of gains and losses) are not cognitively accessible making it possible to dissociate verbal behavior (reports) of consciously inaccessible cognitive processes from overt behavior to precisely measure the latter.

Experimental Analysis of Behavior in Decision-Making and Choice Research

To simulate complex non-hypothetical choice and to precisely measure overt, loss averse behavior, three components of the formal methodology of experimental analysis of behavior (EAB) are utilized: an operant learning procedure is instantiated in the experimental procedure; EAB methods are used to analyze decision-making and choice behavior as a function of its consequences and deviations from matching; and small-*N* experimental design is used to identify and measure the magnitude of functional relationships between obtained reinforcers and punishers and subsequent patterns of choice at the level of the individual, the level at which decision-making and choice behavior occurs.

Operant Learning Procedure

As discussed, decision-making and choice are often complex—the contingencies of reinforcement and punishment, the probability and frequency of consequences, the degree of risk and uncertainty, and effects of temporal constraints, like delay, on utility, are initially unknown. In contrast to research that utilizes hypothetical scenarios in which information about these factors is provided (making the information accessible to conscious cognitive deliberation), in every-day choice this information is often initially unknown until learning from experience with the consequences of operant behavior has occurred. The term *operant* refers to any behavior emitted by an organism that operates on the environment to produce consequences (Marr, 2016). The environment in which operant choice behaviors occur provides a finite set of possible reinforcing consequences. In this way, behavior is understood to come under the control of the environment and the selection of behavioral patterns occurs. An operant learning procedure is used in this study to investigate how individuals allocate behavior between alternatives in non-hypothetical complex choice as they learn from initially unknown contingencies and schedules of reinforcement and punishment.

This study instantiates an operant learning procedure in the experimental apparatus to simulate the process whereby decision-makers make choices based on learning obtained from responding to and experiencing the consequences of their choices rather than on predictions of their own behavior. The instantiation is accomplished via a computer game that presents decision-makers with a series of choice sets. Each set has two concurrent choice alternatives with unique schedules of reinforcement. Participants can freely move between the alternatives and distribute their behavior between the alternatives at any ratio they choose. Playing the game requires participants to click the computer mouse on on-screen moving objects, some of which, according to pre-programmed schedules of reinforcement and punishment, result in the delivery of either a reinforcer or a punisher in the form of a gain or loss of real money or food. If the gains and losses function as reinforcers or punishers, respectively, the participant’s future behavior will be affected. Obtained reinforcers in a particular choice alternative will result in increased clicking in that alternative while obtained punishers in a particular choice alternative will result in a decrease. As predicted by the matching law, as participants continue to learn from the consequences of their choices, their allocation of clicking behavior between the two alternatives (i.e., their choices) should come to resemble the ratio of distribution of available reinforcers in each alternative. For example, if the left- and right-side choices in the computer game are programmed with VI 11-second and VI 100-second reinforcement schedules, respectively, the ratio of available reinforcers is 9: 1 (left: right). As participants learn from experience that their clicks result in obtained reinforcers on the left side 90% of the time and only 10% of the time on the right side, the allocation of their subsequent clicking behavior will shift proportionately. The operant learning procedure is discussed in detail in Chapter 6 Methods.

Experimental Analysis of Behavior

This study utilizes the experimental analysis of behavior (EAB) to investigate choice behavior as a function of its consequences and deviations from matching (in this case, a bias away from loss). The EAB "emphasizes the influence of the environment on observable (overt) behavior, rejects the use of unobservable (covert) events to explain behavior, and views thoughts and feelings as behaviors that themselves need to be explained" (Powell et al., 2016, p. 37). Because the evolutionary psychology and operant learning models of choice discussed in Chapter 2 emphasize the influence of environment on patterns of choice and bounded rationality in humans, the focus of the EAB on behavior as a function of its environmental consequences is well-suited for examination of the conditions under which people choose sub-optimally. Its focus on observable, overt, behavior works well with the intent of this study. The methodology is designed to investigate the behavior of individuals under controlled conditions and is grounded on the assumption that behavior is lawful—controlling stimuli and reinforcing and punishing consequences in the environment act as behavioral determinants (Iversen & Lattal, 1991, p. vii).

As such, the EAB is particularly suited for investigating patterns of decision-making and choice in individuals, the level at which decisions and choices are made.

The EAB is an experimental methodology that provides an effective and efficient method for identifying and measuring the degree and magnitude of functional relationships between the environmental stimuli in the form of reinforcing and punishing consequences of operant behavior (IV) and the allocation of behavior between choices alternatives (DV). This is accomplished by measuring covariance between the IV and DV as the schedules of reinforcement for choice (IV) are systematically varied. By systematically varying the ratios of consequences (obtained reinforcers and punishers in the form of gains and losses of money and food) across multiple sets of concurrent choice alternatives, this study measures the effects of those gains and losses on decision-making patterns. The sample size in the EAB is the number of measurements of the relationship between the IV and DV rather than the number of participants. Thus, measurements of individuals' behavioral response to the IV are taken multiple times, and in the case of this study, hundreds of times.

The unit of analysis in EAB is the rate of responding by the participant (Hansen, 2016). This study measures changes in the rate of responding between choice alternatives to quantify the effect of punishment (loss) in participants whose behavior may be influenced by different choice domains like money or food or by the menstrual cycle. Quantifying the covariation of the rate of responding between choice alternatives and schedules of reinforcement makes possible not only accurate descriptions of decision and choice behavior under these conditions but also predictions of how behavior will be allocated in those conditions—a clear benefit over normative rational choice theory and utility theory models.

Small-N Experimental Design

Because the EAB emphasizes and relies on direct measurement of functional relationships between the IV and the DV from measures of overt behavior of individuals rather than relying on estimations of IV effect on individual behavior derived from group averages, this study utilizes small-*N* experimental design as the preferred methodology for measuring and analyzing decision-making and choice behavior and its environmental determinants at the level of the individual.

Small-*N* is a methodology used to study behavior of individuals. Although numbers of participants are few, large sample sizes in the form of repeated measurements of systematically varied IV effects on the DV are the norm. This practice is due to the widespread view among behavior analysts that to understand contingencies that control individuals' behavior, "It is more useful to study one animal for 1000 hours than to study 1000 animals for one hour" (attributed to B.F. Skinner as quoted in Kerlinger & Lee, 1999, p. 547, as cited in Smith & Little, 2018, p. 2083). The core components of small-*N* experimental designs are "(1) studying a single person or small group of persons over time, (2) repeated measurement of the [IV effect], and (3) the sequential, [systematic] application and withdrawal of (or variation in) [the IV]" (Graham et al., 2012, p. S111).

Advantages of Using Small-N Design in Decision-Making and Choice ResearchThe methodological features of small-*N* designs allow for numerous, distinct scientific advantages. For a comprehensive review of the scientific strengths and advantages of using small-*N* experimental design for research in behavior at the level of the individual, see; Graham et al. (2012); Hensen & Barlow (1984), Virués-Ortega et al. (2016), and Smith & Little (2018). Some of the advantages described in these works that are essential to this study are reviewed here: (a) the advantages of using individual versus group-level analyses, and (b) the advantages of data analytic and interpretation methods in small-*N* experiments.

Individual Versus Group-Level Analyses. Many research questions in the social sciences require analysis at the group level, wherein each participant provides one, or a few, measures, usually cross-sectional, of the IV effect. This methodology requires large numbers of participants to compensate for lack of experimental control (precise measurement of functional relationship between IV and DV), to facilitate statistical control over error variance when estimating the effect of the IV, and to establish effect size of the IV. Group designs rely on average performance of all individuals in a group so estimates and prediction of individual's choice behavior derived from group mean-differences are likely not only to be imprecise in predicting individual behavior but also to obfuscate individual differences such as gender and sex differences. Because small-*N* design uses the individual as the unit of analysis (Graham et al., 2012), this section briefly mentions differences between individual and group-level inference.

One advantage of small-*N* methodology is its excellent control over error variance. Error variance is, "often large and is commonly accepted as an inescapable reality of psychological experimentation. It is a widely held belief that because statistical power is inversely related to error variance, the only recourse when confronted with large error variance is to increase sample size" (Smith & Little, 2018, p. 2087). Small-*N* design provides an alternative method for solving the problem of error variance.

In a series of simulations, Smith & Little (2018) demonstrated the relationship of power, effect size and sample size in individual analyses (small-*N*) versus group analysis (large-*N*). Their findings for individual analyses are summarized as follows: (a) "For individuals sampled with a positive interaction, the individual analysis is very sensitive with the average power greater than .9 even at the lowest levels of the effect" (p. 2092); (b) "From individuals sampled with a null interaction, the individual-level analysis is sensitive even to small effects near zero so that the value of the estimate can be examined to determine its importance rather than relying on a null hypothesis test to decide whether it is or is not actually zero" (p. 2092).

Their findings for group analyses are summarized as follows: (a) "Group analyses show comparable power only when *all* participants show a positive interaction. When any participant from the group is sampled from the null interaction, the power of the analysis drops substantially (from near 1.0 to .3)" (Smith & Little, 2018, p. 2092). In other words, the group-level analysis obscures "individual differences in the presentation of the interaction" (p. 2092); (b) "When *half or fewer* of the participants show an IV interaction, the group-level analysis only very rarely detects an interaction. It seems wholly undesirable that one could conclude in favor of the null hypothesis when half of one's sample shows the effect" (p. 2092); (c) "As expected, the power of the group-level analysis increases as *N* increases, but power to detect effects at the group-level analysis is comparable to the individual-level analysis only at large levels of *N*, [and], the larger *N* is, the more likely the group-level analyses is to obscure qualitative individual differences in the level of the effect" (pp. 2092-2093); (d) "Group-level analyses provide no indication of effect size at the individual level … which the individual-level analysis captures as its primary focus" (p. 2093).

Although all experimental designs—both small-*N* and large-*N* (group comparison)—have limitations, the most misperceived limitation associated with small-*N* research is its inability to establish external validity. However, *replication of the IV effect*, rather than "randomly selecting a representative sample from a large target population is the alternative strategy to establish generalizability in small-N research findings") (Graham et al., 2012, p. S115). Just as is the case in group comparison designs, generalizability "cannot be achieved in the context of a single study but must be developed over time and involve multiple studies, often conducted by different investigators" (Graham, et al., 2012, p. S115.)

In this study, the interaction between the IV (obtained reinforcers and punishers) and the DV (choice behavior) was replicated hundreds of times for multiple subjects.

The Analysis and Interpretation of Data in Small-*N* Designs. Another advantage of small-*N* design is that it avoids common analytical complications associated with group designs. Importantly, findings from group data "will tend to obscure important qualitative individual differences" (Smith & Little, 2018, p. 2084) and can only be used to understand and predict behavior at the level of the individual in terms of any randomly selected individual from the population and assigning a probabilistic IV effect (Graham et al., 2012; Smith & Little, 2018). Because a focus of this study is to detect interactions between qualitative individual differences and environmental stimuli (reinforcing or punishing consequences of behavior) that influence the degree of loss aversion, a small-*N* individual analysis design provides the most precise measurement.

Analytical methods in small-*N* designs have distinct strengths that are well suited for investigating decision-making and choice behavior. First, "the unit of analysis is the individual with each participant serving as her or his own control" (Graham et al., 2012, p. S114) Second,

> Conventional analysis and interpretation in *small-N* research is based on visual inspection of graphed and tabulated data within and across phases. Visual inspection has several advantages: 1) it is intuitive and economical, 2) it provides ongoing information

> regarding changes in the pattern of performance, and 3) it is focused on [individual-level] treatments and responses. (Graham et al., 2012, p. 114)

Third, “effect size calculations (e.g., standardized mean difference approach, regression-based approaches, and visual-based approaches) are widely used as they overcome many of the limitations of *p*-values” (Graham et al., 2012, p. 114). And finally, small-*N* designs are particularly well-suited to investigate potential characteristics that affect participants’ decision and choice behavior, e.g., the factors investigated in this study—individual differences such as gendered behavioral repertories, biological sex differences, menstrual cycle effects, and choice domains. In small-*N* designs, individual participants are assessed repeatedly, and within-subject comparisons are made over time, “allowing patterns of performance to be linked to individuals with specific characteristics” (Graham et al., 2012, p. 114).

Four Factors that May Affect the Expression and Degree of Loss Aversion in Non-Hypothetical, Recurring, Complex, Uncertain and Risky Choice

The purpose of this study is to use operant learning procedures, EAB, and small-*N* experimental design to investigate four factors that may influence patterns of loss averse decision-making and choice behavior. Specifically, this study provides a precise and direct measure of the expression and degree of overt behavioral loss aversion that decision-makers manifest in complex, non-hypothetical choice. Four factors that are likely to impact response to loss are investigated: (a) experience with consequences (the effect of operant learning); (b) the effect of actual gains and losses instead of hypothetical quantities or commodities; (c) the effect of a non-quantitative, primary reinforcer (food); and (d) possible effects of the menstrual cycle.

Factor One: Experience with Consequences of Behavior Allocation in Recurring Choice

Rationale for Investigation. In contrast to common measures of loss aversion that utilize hypothetical scenarios of discrete choice in which information about probable outcomes is presented to the decision-maker, this study utilizes operant learning procedures in which outcomes must be experienced. Operant learning models of decision-making and choice assume that individuals choose to allocate behavior between alternatives based on learning from personal experience with consequences of previous, similar choices. In cases of recurring choice, decision-making and choice behaviors are the result of behavioral selection—reinforced choice behaviors are maintained, strengthened, and become more likely while non-reinforced or punished behaviors become less probable or are extinguished (Donahoe, 2017). In other words, observable patterns of choice behavior are dependent on prior experience and learning that reflect environmental pressures in the form of available reinforcers and punishers. Hypothetical measures present decision-makers with all necessary information needed to perform complex, statistical analyses of probabilities and expected values. These types of tasks and choice problems engage conscious deliberative cognitive processes (System II) to perform complex assessments of mathematical abstractions.

However, information of this type and scope is rarely available in every-day, non-laboratory choice problems. Decision-makers are notoriously bad at computing statistically probable outcomes and making decisions that optimize available rewards. For example, decision-makers tend to underweight high probabilities, overweight low probabilities, and are risk averse, regardless of the expected value of potential gains in the risky choice versus the safe choice (Erev et al., 2008; Haselton et al., 2016; Tversky & Kahneman, 1974). These tendencies hold even for trained statistical experts and for professional investors who consistently prefer investments with safer but lower average rates of returns over those with higher average rates (Benartzi & Thaler, 1995; Erev et al. 2008; Haselton et al., 2016). According to bounded rationality theorists, the lack of proficiency in this type of cognitive task is due to cognitive limitations in processing capacity, which result in heuristical thinking (which works well enough most of the time) and systematic errors in judgment (biases) that result in sub-optimal reward getting and irrationality (Haselton et al., 2016; Tversky & Kahneman, 1974). This view supports a sort of flawed-design approach to cognition. Evolutionary psychologists and functional behaviorists offer a compelling alternative explanation for biased cognition. "If problems presented in the laboratory *are not those for which the human mind is designed*, we should not be surprised that people's responses appear to be systematically irrational" (Haselton et al., 2016, p. 971). Over their evolutionary history, decision-makers have developed mind mechanisms for solving specific types of decision-making and choice problems that occur repeatedly in the natural environment (Haselton, et al., 2016; Herrnstein, 1990). Recurring choice problems must only share salient features, they need not be exact choice alternatives to result in *response classes*: "a group of responses with varying topography which accomplish the same thing, all of which produce the same effect on the environment" (Applied Behavior Analysis, 2018). Information about possible outcomes and their likelihood are rarely, if ever, accessible in every-day decision and choice problems. Instead, consequences of choice are experienced by decision-makers and are perceived and learned as base rates, or frequencies, rather than probabilities, which "are more readily observable in nature" (Haselton et al., 2016, p. 971; see also Gigerenzer, 1998). In studies which presented choice information as frequencies, rather than requiring participants to assess probabilities, optimization increased dramatically and the magnitude of bias decreased (Fiedler, 1988; Haselton et al., 2016; Hertwig & Gigerenzer, 1999; Tversky &

Kahneman, 1983). The evolutionary psychological perspective supports the view that cognitive biases, as viewed through measures of hypothetical discrete choice, can be seen as a design feature of adaptive decision-making, as opposed to a design flaw— "The direction and content of biases is not arbitrary. … [Natural] selection has sculpted the ways that limited computational power is deployed so as best to serve the fitness interests of humans over evolutionary time" (Haselton et al., 2016, p. 971). For example, due to limitations on cognitive processing power, mind mechanisms that rely on perceptively accessible base rates may be more advantageous than the ability to calculate probabilities—a demanding process that may not be sufficiently beneficial in increased accuracy or efficiency to make up for the heavy cognitive costs and expensive resources of time and effort.

Accordingly, using operant learning and experience-based measures of loss aversion may result in a difference in magnitude of the accepted gain-loss asymmetry value, or even no bias, for two reasons. First, the widely accepted original finding by Kahneman and Tversky (1979), and subsequent confirmatory research, indicates that decision-makers subjectively weight losses 2.25 times more than gains of the same objective value. However, this value was determined, in large part, by using discrete choice tasks that require complex cognitive calculations of abstract probabilities. If the mind mechanism responsible for evoking loss aversion developed in response to a need for assessing experienced frequencies of outcomes, then presenting the decision-maker with this type of choice task may result in asymmetry of a different magnitude or no asymmetry at all (Haselton et al., 2016).

Second, adequate experience and learning is required for cognitive mechanisms that rely on assessment of base rates. In natural choice environments, several factors influence the speed and degree to which decision-makers can optimally evaluate base rates of consequences. These include the frequency of choice opportunities, intervals between choice opportunities, delay before consequences are delivered, valence of consequences, and magnitude of consequences, among others. In the early stages of learning, before decision-makers have much experience with consequences and perception of base rates, they may allocate their behavior evenly between the choice alternatives. As consequences available in the environment begin to exert control over the behavior, allocation of behavior toward the richer schedule will occur (melioration) until behavior stabilizes. Measurement of behavior at various points before stabilization and sufficient experience with consequences occurs will likely result in varying degrees of gain-loss asymmetry values. Studies that use hypothetical scenarios only provide information for discrete choice and provide no feedback. In the less common studies that use utilize experiential measures, gain-loss asymmetry ratios vary from non-existent, to confirming the original 2.25: 1 finding, to values as high as 8: 1 (Erev et al., 2008; Mukherjee, 2019; Rasmussen & Newland, 2008; Yechiam et al., 2015).

How this Study Investigates the Factor. Participants' response allocation is observed and recorded continuously over a series of sessions. All participants completed twenty-four 18-minute sessions in unpunished (gains-only) conditions over several days. This procedure established behavioral stability in un-risky choice, a neutral reference point of wealth based on individuals' operant learning experience. Participants then completed up to 16 additional 36-minute sessions in that included gains-only conditions and gains+punishment conditions, comprised of the same schedules as the gains-only conditions but with a superimposed schedule of punishment. Participants in all experimental series experienced consequences of their choice behavior in several uncertain and risky choice sets over several days. Participants experienced consequences of their choices hundreds, and sometimes thousands, of times depending on their preferred rate of responding. Behavior allocation to any given alternative resulted in a gain or loss according to a pre-determined probability distribution that was unknown to the participant. Participants experienced actual consequences—for each gain, additional real money or food tokens were immediately available, and for each loss, real money or food tokens were removed from the participant's total wealth. A running cumulative total of gains and losses was provided as real-time feedback. Automatic, time-stamped recordings of each instance of behavior allocation between alternatives made it possible to determine the degree to which response patterns varied with schedules of reinforcement and punishment, the point at which behavior stabilized (sufficient experience with contingencies), and whether a behavioral bias away from loss, regardless of reward potential, existed. Response behavior was analyzed after eight sessions of punished choice and again after 16 additional sessions. This procedure accounts for learning history from previous experience with consequences of choice to obtain measures of loss aversion that more closely reflect how the bias is expressed in natural choice settings.

Factor Two: Real Gains and Losses of Money and Food Versus Hypothetical Scenarios or Imagined Commodities

Rationale for Investigation. The original research and much of the subsequent foundational research on loss aversion utilizes hypothetical scenarios and relies on verbal report measures (spoken or written) of cognitive and affective strategies and predictions about the hypothetical choices (Kahneman & Tversky, 1979; Yechiam et al., 2019). The hypothetical scenarios include choices of bets and lotteries that require conscious calculations of probabilities and expected value. It is unclear how closely self-reports of cognitive strategizing and affective forecasting about potential loss resemble the actual experience of loss and subsequent behavior changes.

One theory about hedonic asymmetry found in verbal reports is that loss aversion is "commonly thought to occur because people expect the pain of losing something to exceed the pleasure of gaining it" (McGraw et al., 2010, p. 1441). This belief may be partly due to the widespread education and acceptance in social science fields that losses loom larger than gains (the psychological or subjective value of losing $100 is much more than the value of gaining $100), a belief that is widespread and has remained mostly unchallenged since the advent of prospect theory in the 1980s (Mukherjee, 2019). The expectation that losses loom larger than gains may also be due to a more general bias—adding components to a choice set is seen as more favorable than removing components, even when removing options or components results in more optimal outcomes (Adams et al., 2021).

Despite loss averse trends in verbal behavior of hypothetical choice, some studies indicate that even when participants predicted losses would be more impactful than gains, when the outcomes were experienced, losses did not produce the level of expected emotional impact (Kermer et al., 2006; Mukherjee, 2019). A possible explanation is that the "purported asymmetrical impact of losses versus gains is a property of affective forecasts and not of actual experience" (Mukherjee, 2019, p. 2; see also Kermer et al., 2006, Harinck et al., 2007; Mukherjee et al., 2017). As an example, Yechiam et al. (2014) found that asymmetry between positive and negative events did emerge at the affective level when participants predicted their response to lotteries that included high losses, but the asymmetry was not apparent in subsequent evaluations and choices—participants did not avoid lotteries with the highest losses. They concluded that asymmetrical affective responding resulted from a complaint bias—the tendency to complain about negative events while not acknowledging positive events as much, and that the verbal reporting of asymmetrical affect towards losses was part of strategic reasoning.

Measures of loss aversion using hypothetical scenarios are dependent on verbal reports (spoken or written), and are, at best, inferred measures of cognitive bias and not direct measures of preference for behavior allocation between choice alternatives (De Houwer, 2019). Although verbal reports can tap into accessible affect and conscious cognitive processing, loss aversion, as an unconscious cognitive bias that affects behavior allocation, likely occurs at the level of System I cognitive processing—fast, perceptual, automatic, associative, and inaccessible to conscious deliberation. Verbal reports and conscious cognition are behaviors that may reveal a conscious negative affective bias away from losses, but the question remains if actual behavior allocation is unconsciously biased away from losses in the same way.

How this Study Investigates the Factor. Rather than using hypothetical scenarios that required conscious calculation of probability or expected utility, this study uses a computer game that makes gains and losses of real money or food tokens (exchanged for real food) available on systematically varied schedules of reinforcement and punishment. When experiencing gains and losses of money or food, rather than predicting how they will feel or respond, participants respond by distributing future resources (time and effort) between choice alternatives. As participants play the game, they freely distributed their between two choice alternatives. According to predetermined schedules, clicking on the objects occasionally results in the delivery of a gain or a loss of actual money or actual food. The behavioral responses are automatically recorded and the patterns of behavioral distribution are analyzed for covariance with reinforcement schedules and bias (bias parameter, log *b*, from generalized matching law) away from losses.

By using actual money and food, rather than hypothetical scenarios, this study has the potential to provide supporting evidence for loss aversion as an unconscious, cognitive bias that influences patterns of behavioral responding and resource allocation rather than solely as a verbal behavior report of conscious cognitive and affective forecasting or strategizing.

Factor Three: Gains and Losses of a Non-Quantitative, Primary Reinforcer (Food)

Rationale for Investigation. Loss aversion, as predicted by prospect theory, was "supposed to be a general hypothesis about 'something'" (Mukherjee, 2019, p. 1), about a behavioral model capable of predicting how cognitive limitations affect people's decisions between alternatives across all choice domains that involve risk and uncertainty. However, the original research that resulted in prospect theory was conducted in the monetary and quantitative domain (Mukherjee, 2019). Prospect theory assumes that people think in terms of changes relative to a reference point (e.g., current wealth state) rather than absolute outcomes. Kahneman and Tversky originally calculated an asymmetry value wherein quantitatively defined loss was weighted subjectively more than a monetary gain of the same objective value by a factor of 2.25 (Kahneman, 2003). The subsequent application of prospect theory to economics and behavioral economics transformed classic economic theory and as a result, most of the confirmatory and exploratory research on loss aversion has been conducted in the economic and monetary domain (Mukherjee, 2019).Research in the monetary domain has made the identification and quantification of loss aversion possible because both the hypothetical situations and the monetary outcomes are easily quantifiable and qualitatively similar. The use of familiar quantitative choice alternatives, the use of probability estimates (e.g., % likelihood of gains or losses), and the use of qualitatively and quantitatively similar choice outcomes (gains and losses of money), have resulted in the common emphasis on hypothetical scenarios and verbal report measures of cognitive strategizing and affective forecasting about gains and losses of money. These methods lend support to an understanding of loss aversion as a cognitive strategy or affective prediction about gains and losses of money but do little to establish loss aversion as an unconscious, cognitive bias that affects behavioral responding or to establish loss aversion as a general principle of decision-making and choice in conditions of uncertainty and risk, regardless of choice domain or commodity type.

Research in non-quantitative choice domains is needed to determine if loss aversion is a phenomenon limited to consciously accessible quantitative information or if it is a more general principle of behavioral responding to uncertain and risky choice, but there are experimental challenges to extending research of loss aversion to non-quantitative choice domains. Expected utility theory presumes that there is some basic unit of utility that decision-makers apply to any risky decision problem to calculate risk but ascertaining a unit value of utility across domains remains a difficult research problem. For example, a choice of an investment of time and effort may result in a monetary gain, the utility of which is easily quantifiable, but may have potential social costs or food-opportunity costs, and the utility of the costs is not easily quantifiable or comparable to monetary costs. An investment of time and effort may result in proximal social gain and gains of consumables (social eating and drinking) but result in delayed health costs. These kinds of decision scenarios are common outside the laboratory, but unlike monetary choice, the quantification and measurement of gains and losses necessary for calculating gain-loss asymmetry values in non-quantitative domains, like decisions involving food, make comparative quantification challenging.

It is possible that choice with certain features—e.g., complexity, uncertain schedules of reinforcement, and risk of loss—may evoke similar decision-making and choice processes regardless of commodity, choice domain, or choice involving single or multiple domains. In this case, a general decision-making principle of bias that allocates response behavior away from loss should be apparent for all types of decisions involving uncertainty and risk, e.g., decisions that involve time, effort, social currency and status, and wealth.

To test if loss aversion is a general principle of decision-making in recurring, complex, uncertain, and risky choice, this study examines the allocation of behavioral resources (effort and time) in complex, uncertain and risky choices with food—a primary reinforcer and a non-quantitative choice domain.

The rationales for using food as an alternative to money to investigate patterns of loss averse behavior are twofold. First, if individuals exhibit patterns of loss-averse behavior with food, the concept of loss aversion as a general principle of decision-making in uncertain and risky choice, rather than a monetary and wealth-bound phenomenon, is strengthened. Conversely, if patterns of loss-averse behavior with food are not experimentally observable, it may indicate that loss aversion is a phenomenon limited to cognitive and affective strategizing and prediction in the monetary/wealth domain. The absence of loss aversion with food may also indicate that underlying cognitive mechanisms for decision-making and choice may be domain dependent. In other words, the carrier of utility (commodity) and its biological relevance may be affected by different underlying biological decision-making mechanisms: non-consumable commodities used for trade and barter to secure biologically relevant rewards; non-consumable commodities used to increase social status or hedonic appetite; vital, consumable commodities like food; and hedonistic consumables like alcohol, soda, candy, cigarettes, etc., may all be regulated by different underlying mechanisms (Estle et al., 2007).

For example, food is a consumable, primary biological reinforcer necessary for survival and there are well-known physiological pathways for appetite, reward, and managing scarcity. There is some evidence that consumable rewards evoke more risk aversion and are temporally discounted at a higher rate than non-consumable rewards which will affect asymmetry values (Estle et al., 2007; Odum et al., 2006). There are also learned emotional and social features of rewards and punishments of food. In contrast, money is a non-consumable, conditioned, secondary reinforcer with no direct biological relevance (although, it too has learned emotional and social features associated with its gain and loss which might tap in to similar, biologically based decision-making processes) (Lea & Webley, 2006).

A second rationale for using food as an alternative to money is that if gain-loss asymmetry values of food differ meaningfully from those found in the quantitative research, it would suggest that loss aversion is functionally dependent on context and commodity.

How This Study Investigates this Factor. The emphasis on hypothetical choice in the monetary domain has provided an enormous literature on conscious cognitive strategy and affective forecasting in which measures of participants' affective response and expectations of their behavior have shaped the common understanding of loss aversion. The design of this study seeks to determine if behavioral patterns of loss averse responding are observable in non-quantitative choice domains, such as choice with food, a primary, consumable biological reinforcer. Participants are exposed to the exact experimental procedures as those in choice with money, except they are voluntarily deprived of food for 10-14 hours during their normal fasting period (from the last meal on one day to the first meal of the next day), and they play the computer game for gains and losses of real food rather than money.

Factor Four: The Menstrual Cycle

Rationale for Investigation. In addition to the possibility that cognitive biases have developed as an adaptive response mechanism, evolutionary psychologists and socio-biologists propose that, rather than a design flaw resulting in sub-optimal rationality, cognitive biases are adaptive in contexts like those in which underlying mind mechanisms were selected and can even result in context-dependent optimization in decision-making and choice (Haselton et al., 2016). “[This] perspective predicts that the mind is equipped with function-specific mechanisms adapted for special purposes—mechanisms with special designs for solving problems such as mating, which are separate, at least in part, from those involved in solving problems of food choice, predator avoidance, and social exchange” (Kenrick et al., 2010, p. 64).

Recall that behavior is the result of an interaction between (a) the individual’s biology (biological substrates of behavior that makes response and behavior mechanisms possible), (b) the individual’s behavioral expression (the set of observable behavioral characteristics of an individual resulting from the interaction of its biological capacities with the environment), and (c) the individual’s learning history (the behavioral repertoires selected via experience with consequences available in the environment). As discussed in Chapter 2, sex differences in biological substrates of behavior are well known for choices involving mate selection, mating behaviors, reproduction costs, predator (threat) avoidance, food procurement for self and offspring, and food choice, e.g., females have fluctuating caloric and nutritional needs during pregnancy, lactation, and possibly across menstrual cycle phases. Additionally, behavioral expression will reflect choice behavior as a product of a learning repertoire shaped in gendered environments and consequences available in the local, gendered environment. Gender differences will be manifest for choices involving differential access to resources (wealth-earning opportunities, education, decision-making roles that determine allocation of resources, etc.), differential threat types and prevalence, social exchange, and social currency.

It is, therefore, plausible that sex and gender specific biological and behavioral response mechanisms have been selected for at every level of the behavioral triad—the individual, the environment, and the individual's behavioral repertoire interacting in the environment—for *optimally* responding to decision tasks. The following discussion demonstrates the plausibility that biased, loss-averse patterns of behavior may be differentially adaptive for males and females and can even result in overall, optimal patterns of decision-making and choice.

Research by Haselton et al. (2016) utilizes error management theory (EMT), which "applies principles from signal detection theory to judgment tasks in order to make predictions about evolved cognitive mechanisms" (p. 972). Rather than some sort of mechanism that can determine optimal behavior allocation in each novel situation (Fodor, 2001; Haselton et al., 2016), the error management framework views cognitive and behavioral mechanisms as "adaptation executors" (Haselton et al., 2016, p. 972; see also Tooby & Cosmides, 1990). However, because most decision tasks "are probabilistic and include an irreducible amount of uncertainty" (Haselton et al., 2016, p. 972) and risk (costs or potential loss), the mechanisms will invariably have a high probability of decision error resulting in sub-optimal outcomes *for any single decision task*. A central tenet of EMT is that:

> Cognitive mechanisms generally produce two types of errors: false positives (taking an action that would have been better not to take) and false negatives (failing to take an action that would have been better to take) … and the fitness costs of each type of error are seldom equal. Fleeing from an area that contains no predator results in a small inconvenience cost, but it is much less costly than the failure to flee from a predator that really is close by. (Haselton et al., 2016, p. 973)

In the absence of sufficient opportunity for learning and experience, and because errors are asymmetric in high versus low costs, a behavior mechanism that prevents high-cost, fitness-reducing errors would be optimal. "Importantly, EMT predicts that an optimal decision rule will minimize not *the total error rate,* but *the net effects of error on fitness* [emphasis added] (Haselton et al., 2016, p. 973).

From this framework, many supposed flaws in human judgment, decision-making and choice that appear to be irrational, may reflect the operation of behavioral mechanisms selected "to make inexpensive, frequent errors rather than occasional disastrous ones" (Haselton et al., 2016, p. 973; see also Johnson & Fowler, 2013).

The following example by Haselton, et al. (2016) proposes a case study of how risk assessments, and their associated judgment errors—false positives and false negatives—in the social choice domain, can be differentially costly for females and males. In each case, it is clear how loss aversion, a bias away from loss or cost, results in a differentially optimal response pattern (Haselton et al., 2016).

In the social choice domain, women must make decisions regarding a potential mating partner's capability and willingness to commit, an inference of commitment. A false positive error occurs by inferring interest to commit where there is none, the cost of which is high—desertion by a mate. A false negative error occurs by inferring unwillingness to commit where there is willingness, the cost of which is relatively low (in terms of fitness)—delayed start to reproduction. In this type of choice and domain, when errors in assessing risk occur, it is optimal for women to make false negatives, be more risk averse, and more loss averse (unwilling to risk loss due to its potentially disastrous effects).

In contrast, in the same choice domain, males must make decisions regarding a potential mating partner's sexual interest, an inference of female sexual interest. A false positive error occurs by inferring sexual interest where there is none, the cost of which is relatively low—rejection by a potential partner. A false negative error occurs by inferring no interest when interest exists, the cost of which is high (in terms of fitness)—missed reproductive opportunity. In this type of choice and domain, when errors in assessing risk occur, it is optimal for men to make false positives, be more risk-seeking, and less loss averse—willing to endure several small losses to prevent missing any possible mating partners.

This example demonstrates that varying degrees of loss aversion could be an optimal response pattern to uncertain and risky choice in the social domain with underlying reproductive consequences. Although it remains unclear whether loss aversion is an optimal response pattern across all choice domains that involve uncertainty and risk, a large proportion of uncertain and risky choices *do* have underlying consequences for fitness and reproductive success. These include not only choices about mating and reproduction, but also ensuring health and survival of self and offspring, which is optimized by greater access to resources, including monetary wealth, calorie- and nutrient-sufficient foods, social status and currency, and so on. Because the costs and risks of reproduction are asymmetrical in both quality and magnitude for women and men, both evolutionary psychology and EMT frameworks predict that function-specific and sex-specific cognitive and behavioral mechanisms may have evolved for optimal error management and, therefore, increased fitness. Overall, then, "EMT predicts that biases will evolve in human judgments and evaluations that fit the following criteria: (a) they involve some degree of noise or uncertainty, (b) they have consequences for fitness and reproductive success, and (c) they are consistently associated with asymmetrical costs (where more asymmetry leads to larger biases)" (Haselton et al., 2016, p. 973).

Because of high reproduction costs for women, to ensure reproductive and fitness success, a behavioral response mechanism that minimizes the risk of committing high-cost false positive or false negative errors in uncertain and risky choice related to reproduction would be imperative. Also, it is likely that the asymmetrical costs of committing one type of error versus another would be dependent on the aspect of reproduction and the broader choice domain in which decisions are made. For example, there are different types and degrees of cost associated with reproduction in the social domain: recreational sex, risky sexual behavior, predator avoidance, mate selection (which includes assessment not only of physical traits but also social status and currency); in the monetary wealth and resource domain: care, protection, and providing maximum benefits for survival to self and offspring requires sufficient access to resources; and in the food domain: not only do offspring require adequate access to sufficient calories and nutrients, but women have varying caloric and nutritional requirements at various points of the menstrual cycle, during pregnancy and while lactating.

The underlying physiological processes that regulate reproduction in women are a complex system of cyclically fluctuating hormonal interactions between the hypothalamus, anterior pituitary gland, and ovaries—the menstrual cycle. The cycle consists of three broad categories, or phases, based on ovarian status—follicular, ovulatory, and luteal. Each phase is associated with a particular profile of pituitary and gonadal hormones—follicle-stimulating hormone (FSH) and luteinizing hormone (LH), and, progesterone and estrogens, respectively (National Library of Medicine, 2021).

Given the high cost and the possible consequences for reproduction in uncertain and risky choice, a correlation of cognitive and behavioral mechanisms that favor more, or less, risk aversion and loss aversion with menstrual cycle phases seems plausible. For example, negative consequences associated with mate selection, recreational sex, risky social behavior, and predator avoidance may have more value during the peri-ovulatory phase when conception is possible. Negative consequences associated with toxic or harmful consumables, e.g., alcohol, drugs, cigarettes, or spoiled food may have more value during the luteal phase when implantation occurs. In contrast, rewards of food, and certain types of food, may have more value from the late follicular phase through the luteal phase as the endometrium grows, or, in the luteal phase when implantation is possible.

The previous examples are hypothetical conjecture of decisions and choice that may be relevant to reproduction, but which have uncertainty and risk as a key feature. There is an extensive body of published research citing not only reproduction-related behavioral correlates with menstrual cycle phases but also ascribing causal effects on almost every conceivable social behavior, the majority of which are not explicitly reproductive. For example, menstrual cycle effects have been cited for cognitive functioning and emotional processing (Derntl et al., 2014; Mordecai et al., 2008; Zhang et al., 2013); food consumption (Saad & Stenstrom, 2012); implicit motivation (Schultheiss et al., 2003); ratings of trustworthiness (Ball et al., 2013); competitiveness (Buser, 2012); dress and grooming (Durante, 2008; Haselton et al. 2016); voting tendencies (Durante et al., 2013); intra-sex dehumanization (Piccoli et al., 2013); preferences for symmetry (Cárdenas & Harris, 2007); product preferences, prosocial orientation and charitable-giving (Stenstrom et al., 2018); cooperative preferences (Anderl et al., 2015); and so on.

Regarding "menstrual-cycle-related changes in behaviors that are not explicitly reproductive … the common theoretical goal has been to provide an evolutionary explanation for behaviors that appear to fluctuate across the menstrual cycle" (Kiesner et al., 2020, p. 1113). The extent and diversity of behaviors attributed to menstrual cycle fluctuations are dizzying and if the literature is to be taken at face value, it appears that a woman's decision and choice behavior is wholly determined by the phase of the menstrual cycle in which she happens to be at the time of choice. Given the number and kind of the behaviors reported to vary with the menstrual cycle, it is highly unlikely that the menstrual cycle alone will sufficiently explain the behavior: physiological, physical, psychological, and social influences (Kiesner et al., 2020), as well as previous learning, experience, and available consequences in the local environment, likely all play a role.

The paradigm of thought that attributes non-reproductive related behaviors to the menstrual cycle is highly problematic and reminiscent of a damaging pattern in research that has persisted far too long—the reduction of women's complex human behavior to their reproductive biology. Some of the several limitations of these studies include:

> The exclusive focus on proximity to ovulation as the driving force of cyclical changes in behavior rather than balanced attention to [events that occur throughout the cycle]; the lack of attention to individual differences; [and] the reliance on theoretical models that fail to consider or specify pathways involving the many biological, physical, psychological, and social changes that are associated with the menstrual cycle. (Kiesner et al., 2020, p. 1113)

These limitations and the lack of attention to several menstrual-cycle-related physical symptoms "may result in third-variable confounds" that compromise the internal validity of the studies (Kiesner et al., 2020, p. 1113). For example, while ovulation and menstruation are key signposts that mark critical transition points and particular pituitary and gonadal hormone profiles, they are only two of many physiological and physical changes that occur cyclically. Physical symptoms include headaches/migraines, lower abdominal cramps, bloating, weight gain, breast pain, back pain, headaches, acne, lower abdominal cramps, and so on (for a review, see Kiesner, et al., 2020). Also, cyclical "physiological changes in the immune system, the digestive system, the cardiovascular system, and thermoregulation" may have interactive effects on functions throughout the body (Kiesner et al., 2020, p. 1115; see also Farage et al., 2009). Any of these physical changes can result in cognitive, behavioral, and psychological symptoms: depressed mood, changes in support seeking, social withdrawal, irritability, decreased sexual interest, changes in dress and grooming to accommodate physical changes, body-image dissatisfaction, decreased physical activity, immobility due to pain, decreased energy, and so on. For a review of cognitive, behavioral, and physiological symptoms that can be directly related to physical changes across the menstrual cycle, see Farage et al. (2009) and Kiesner et al. (2020).

The potentially confounding physical changes that occur during the menstrual cycle are not exclusive to the menstrual cycle—non-cycling people may feel irritable and withdraw socially when they have back pain, headache, and bloating. Although these behaviors cannot be attributed exclusively to the menstrual cycle, cyclical physiological and physical effects of the menstrual cycle, taken as a whole or in part, may act in a way that affects the value of consequences, and therefore behavior allocation, in decision tasks. Anecdotal reports of increased valuation of pleasure foods (e.g., ice cream) during a physically uncomfortable peri-menstrual phase are not uncommon. Behavioral analysts, refer to such events as *motivating operations*. Motivating operations are "environmental events, operations, or stimulus conditions" that have two main effects on behavior: a value-altering effect (they alter the reinforcing or punishing value of other environmental events—consequences), and a behavior-altering effect (they alter the frequency of operant response classes related to the altered consequences) (Laraway et al., 2003, p. 407).

Note that the goal of this study is not to prove the evolutionary function of a response pattern associated with the menstrual cycle, nor is it to demonstrate that women's choices with money and food are governed by the cyclical hormonal fluctuations of the menstrual cycle.

Rather, the intent is to investigate the possibility that patterns of loss averse behavior may vary with menstrual cycle phases when uncertainty and risk are more, or less, salient. Two possible explanations for covariance of loss aversion with points of the menstrual cycle are that loss aversion is the result of an evolved adaptive cognitive and behavioral response mechanism, or because some feature or effect of the menstrual cycle acts as a motivating operation. By direct investigation, this study (a) explicitly addresses women's decision and choice behavior, (b) discards the rationale for centuries of female sex exclusion in psychological, behavioral, biological, medical, pharmacological, and physiological research—that cyclical fluctuating hormones in females increase experimental variability and makes data uninterpretable, and (c) promotes the concept that patterns of choice behavior that appear irrational when viewed from male-centric and non-contextual frameworks, may actually be serving an overall-optimization function given the consequences of choice available in the local environment.

Although temporal correlations are insufficient, the presence of loss-averse response patterns that manifest across multiple choice domains, e.g., money and food, and vary *with* menstrual cycle phases, would strengthen the notion that underlying physiological processes that regulate reproduction in women are correlated with decision and choice behaviors in conditions of uncertainty and risk. If patterns of loss aversion do not vary with cycle phases, the insidious myth of the irrational female and its ties to the menstrual cycle are further dismantled.

How This Study Investigates this Factor. The design of this study directly investigates whether patterns of responding to gains and losses of money and food vary with three hormonally distinct points of the menstrual cycle. Hundreds of within-subject behavioral measures of women's (and a matched control group of men's) behavioral allocation in operant learning tasks across regularly cycling women and non-cycling men are analyzed. Menstrual cycle points for individuals are determined from assessment of cycle regularity and phase occurrence rather than average measures of phase-timing or average blood volume configurations. The experimental tasks were designed to minimize the salience and impact of reproduction-related or gender-related social expectations and performance demands. Women are tested throughout their cycles at distinctive transition points in which four major hormone classes have the most distinctive profile—menses-onset, peri-ovulatory, and mid-luteal points. Matched male control groups were tested at intervals matched to their female counterparts. The methods for assessing regularity, determining cycle phase, matching groups of women and men, counterbalancing testing order, and the experimental manipulations are discussed in detail in the methods section.

Research Questions, Hypotheses, and Rationales

The four factors likely to influence the expression and degree of loss aversion in recurring, complex, uncertain, and risky choice, are investigated in a series of four experiments. The research questions, hypotheses and rationale for each experiment are as follows.

Experiment One: Gain-loss Asymmetry in Recurring, Complex Choice Under Conditions of Uncertainty and Risk with Real Gains and Losses of Money

Research Question 1. Is loss aversion (the asymmetrically greater behavioral effect of losses, relative to gains) in recurring, complex, uncertain, and risky choice with real gains and losses of money (a generalized reinforcer) a replicable phenomenon of decision-making and choice behavior? And, if gain-loss asymmetry is observable in these conditions, how do obtained gain-loss asymmetry ratios compare to those reported in cognitive and behavioral literature? (Garnica, 2016; Kahneman & Tversky, 1979; Rasmussen & Newland, 2008)

i. Do dimes function as reinforcers, i.e., make future responding more likely to occur?

ii. Do losses of obtained dimes act as punishers, i.e., make future responding less likely to occur?

iii. Is there an identifiable, quantifiable, functional relationship between response allocation among alternatives and reinforcement schedules of coins?

Hypothesis 1. It is expected that gain-loss asymmetry will be observable in recurring, complex, uncertain, and risky choice with potential gains and losses of real money and that asymmetry estimates will differ meaningfully from estimates reported in the cognitive literature. Neither the magnitude nor direction of the difference is predicted.

Rationale 1. If loss aversion is a behavioral phenomenon as well as a phenomenon of conscious, cognitive, and affective forecasting and strategizing, loss aversion should be measurable as a pattern of behavior allocation (a distribution of resources such as effort, time, money, between choice alternatives). The predicted difference in asymmetry estimates in behavioral versus cognitive research is because of the predicted discrepancy between cognitive and affective forecasting and real experience.

Research Question 1a. How do the behavioral effects of losses of money, relative to gains, change over time with repeated learning experience (from four to 16 sessions)?

Hypothesis 1a. It is expected that gain-loss asymmetry estimates will change meaningfully with repeated exposure to unpunished and punished choice with gains and losses of money. Neither the magnitude nor the direction of change is predicted.

Rationale 1a. It is possible that sensitivity to reinforcement will increase, the effects of loss will be attenuated, and responding will shift in the direction of matching. It seems equally likely that, if participants experience a relatively large asymmetrical hedonic effect of loss, they may instead increasingly avoid potential loss.

Research Question 1b. When data is collected and reported in a sex-disaggregated fashion, are there any indications of possible sex/gender differences in gain-loss asymmetry in choice with money? No hypothesis is provided for this exploratory question.

Experiment Two: Gain-Loss Asymmetry Loss Aversion in Recurring, Complex Choice Under Conditions of Uncertainty and Risk with Real Gains and Losses of Food

Research Question 2. Is loss aversion a generalizable principle of decision-making and choice across choice domains, e.g., in a non-quantitative choice domain of food? Is gain-loss asymmetry replicable in recurring, complex, uncertain, and risky choice with gains and losses of real food (a primary reinforcer)?

i. Do food tokens (exchanged for real food) function as reinforcers, i.e., make future responding more likely?

ii. Do losses of obtained food tokens act as punishers, i.e., make future responding less likely?

iii. Is there an identifiable, quantifiable, functional relationship between response allocation among alternatives and reinforcement schedules of food tokens?

Hypothesis 2. It is expected that patterns of loss-averse responding will be apparent in recurring, complex, uncertain, and risky choice with gains and losses of real food.

Rationale 2. Because food is a primary reinforcer necessary for survival, it is likely that decision and choice mechanisms have developed to ensure the most consistent and reliable supply possible and that avoiding losses of current food supplies may compete with the utility of pursuing further gains.

Research Question 2a. If gain-loss asymmetry is found to occur in recurring complex, uncertain and risky choice with food, how do asymmetry estimates compare with those reported in choice with real money?

Hypothesis 2a. It is expected that gain-loss asymmetry estimates will be meaningfully higher for decisions with food than in similar conditions with money.

Rationale 2a. Some research indicates that consumable rewards evoke more risk aversion and individuals may temporally discount consumable commodities at a higher rate than non-consumable commodities (Estle et al., 2007; Odum et al., 2006). Food, a consumable commodity, may, therefore, have more value, both for gains and for losses, than money.

Research Question 2b. How do the behavioral effects of losses of food, relative to gains, change over time with repeated learning experience (from four to 16 sessions)?

Hypothesis 2b. It is expected that gain-loss asymmetry estimates will change meaningfully with repeated exposure to unpunished and punished choice with gains and losses of food. Neither the magnitude nor the direction of change is predicted.

Rationale 2b. It is expected that, over time and with repeated exposure to unpunished choice, learning will occur. It is possible that sensitivity to reinforcement will increase, the effects of loss will be attenuated, and responding will shift in the direction of matching. It seems equally likely that, if participants experience a relatively large asymmetrical hedonic effect of loss, they may instead increasingly avoid potential loss.

Research Question 2c. When data is collected and reported in a sex-disaggregated fashion, are there any indications of possible sex/gender differences in gain-loss asymmetry in choice with food?

Hypothesis 2c. It is expected that gain-loss asymmetry estimates obtained from recurring, complex, uncertain, and risky choice with gains and losses of real food will be meaningfully higher in women than those obtained from men.

Rationale 2c. It is hypothesized that women will exhibit higher loss aversion bias-values than men in decisions with food for two reasons. One, the gendered environment in which women make decisions and choice means that, overall, they have less access to opportunities and resources (earnings, education, property, policy-making positions, etc.) and the cost for losing resources may be experienced as more costly due to perceptions of likelihood of access to resources in the future. Decision-making and choice behavioral repertoires that have developed in response to uncertainty and risk may be more loss-averse, overall. A general bias of this sort would be manifest across choice domains. Two, because of high costs related to reproduction, it is plausible that females are more loss averse as a mechanism of error management that is biased towards certain types of errors to avoid more devastating errors. Avoiding potential losses from a current food supply, a primary reinforcer necessary for survival of self and offspring, rather than pursuing gains of future food supplies, may be just such a bias.

Experiments Three and Four: Correlates of the Menstrual-Cycle and Gain-Loss Asymmetry in Recurring, Complex Choice Under Conditions of Uncertainty and Risk with Real Gains and Losses of Money and Food

Research Questions 3. Do gain-loss asymmetry estimates observed in recurring, complex, uncertain, and risky choice with money vary with three points of the menstrual cycle (menses-onset, peri-ovulatory, and mid-luteal)?

i. Does sensitivity to reinforcers of money in gains-only conditions vary with points of the menstrual cycle?

ii. Does the degree of disruption in sensitivity to reinforcers of money in gains+punishment conditions vary with points of the menstrual cycle?

Hypothesis 3. It is not expected that gain-loss asymmetry estimates in choice with money will vary meaningfully with points of the menstrual cycle.

Rationale 3. It is assumed that biological processes selected to regulate reproduction will not influence decision-making and choice with money when the choice is distinct and isolated from social meaning or mating repercussions. Although beliefs and learned behaviors surrounding the menstrual cycle likely influence non-reproductive behaviors, the experimental design minimized social expectations and performance demands related to beliefs about the menstrual cycle.

Research Questions 4. Do gain-loss asymmetry estimates observed in recurring, complex, uncertain, and risky choice with food vary with three points of the menstrual cycle (menses-onset, peri-ovulatory, and mid-luteal)?

i. Does sensitivity to reinforcers of food in gains-only conditions vary with points of the menstrual cycle?

ii. Does the degree of disruption in sensitivity to reinforcers food in gains+punishment conditions vary with points of the menstrual cycle?

Hypothesis 4. It is expected that gain-loss asymmetry estimates in choice with food will vary meaningfully with points of the menstrual cycle.

Rationale 4. It is plausible that the phases of the menstrual cycle, and their associated physiological effects and physical symptoms, function as motivating operations to influence the value of available gains and losses of food in the environment. Some research suggests that caloric and nutritional intake and needs vary across the menstrual cycle (Barr et al., 1995; Brien, 1996; Dalvit-McPhillips, 1983; Tangney et al, 1991) so it is also plausible that loss and risk are more salient at different points of the cycle as reproductive and nutritional needs and costs fluctuate.

Chapter 5: Methods

To address the research questions, the procedure utilized an operant learning procedure in which participants' behavior allocation between two concurrent choice alternatives was measured continuously over six choice sets in several sessions across days and weeks. The operant learning component was based on two predictions from the generalized matching law. First, the observed ratio of behavior distribution between the left and right choice alternatives is a function of the ratio of obtained reinforcers (actual money or food) earned in the left and right choice alternatives of the computer games. Second, as the consequences from allocating behavior to each choice alternatives are learned, the response ratios will approach matching but deviate according to sensitivity (acuity in perceiving available rewards and punishers) and bias (a preference for one alternative over another despite reinforcement schedules). Choice, the allocation of behavior between alternatives, is operationalized as the rate, quantity, and duration of clicks of a computer mouse in each choice alternative. Each set of choice alternatives consisted of systematically varied schedules of reinforcement and punishment—gains and losses of real money or food. The same general method was used in all experiments. The modifications of procedure, measurement, and analytical methods necessary to answer specific research questions, are explained in detail in the "Experiment-Specific Method and Procedures" section.

IRB, Recruiting, Screening and Enrollment, and Informed Consent

All experimental procedures, recruiting methods, screening procedures, and procedures and provisions for the participants were approved in advance by the Brigham Young University (BYU) Internal Review Board for Human Subjects.

Participants, women and men aged 18-25 years, were recruited from the student population at BYU and from the local community. Recruiting techniques included on-campus and off-campus flyers, in-class announcements, email to university class lists, social-media posts, word of mouth, and BYU's online research-participation registry, SONA.

Applicants were eligible for all studies if they were at least 18 years old and no older than 25 by the end of the study. Applicants were eligible for the food studies if they had a minimum body mass index (BMI) of 18.5 or greater and had the ability to go without eating during their normal fasting period (from the last meal of one day to the first meal the next day) for a maximum of 14 hours. Exclusion criteria included metabolic or digestive disorders such as hypoglycemia, hyperglycemia, diabetes, pre-diabetes, Crohn's disease, Celiac's disease, etc.; a BMI less than 18.5; a history of eating disorder such as binge eating disorder, bulimia nervosa, or anorexia nervosa; ultra-restrictive diets or weight-loss plans such as gluten-free, Vegan, or Keto, etc.; health-threatening food allergies; extreme exercise regimens (more than 2.5-3 hours of recreational or 1.5 hour of intensive exercise between the hours of 5 p.m.-11 a.m.); or a history of adverse effects from fasting.

Female applicants were eligible for the menstrual studies if they had self-reported regular menstrual cycles (consistent 25–35-day cycles) for the previous three consecutive months; had not skipped any cycles in the previous six months; were not pregnant or planning to become pregnant during the study; were not currently using any form of hormonal contraceptive or treatment, including creams, gels, or lotions, and were not planning to do so for the next six months.

Participants signed an informed-consent agreement, were provided with a copy of the agreement, and were informed that their participation was entirely voluntary—they were informed of the right to withdraw at any time or refuse to participate entirely without jeopardy to their class status, grade, standing with the university, or relationship to BYU or the researchers.

General Method and Procedures

Experimental rooms, set-up, equipment, general methods, and experimental procedures were the same across all experiments.

Measurement and Equipment

Participants played a computer game in one of four identical 9 x 9 ft rooms containing a built-in desk and chair. The table held a Dell® desktop computer equipped with a 17 in monitor, computer mouse and speakers. Also positioned on the table were three containers—a large source container that held a few hundred coins or food-tokens (depending on the experiment) and two smaller containers labeled “gains” and “losses.” The coins were dimes (US $0.10; 10¢) in all money studies, and the food tokens were small, coin-sized plastic replicas of food items such as bread, meat, fruit, vegetables, etc. Depending on the experiment, participants played either a SubSearch or FoodSearch computer game that provided systematically altered schedules of reinforcement or punishment (gains or losses of dimes or food tokens). Behavioral responses to available reinforcers and punishers were measured as clicks of the computer mouse. In experiments one and two, each click that occurred during a session was coded, time stamped, and saved to an external MySQL® database. In experiments three and four, responses were automatically recorded in a MySQL Lite® database on Box, the host university’s cloud-based data storage service. At the conclusion of each experimental session, participants brought their “gains” container, of either dimes or food tokens, to a common laboratory room where a research assistant verified by cross-checking their earnings with the results of the computer game. Participants exchanged their earnings in dimes for more convenient currency and their food-token earnings from a large, varied selection of food items. (See Figure 2 and Appendix A *FoodSearch Order Sheet and Personal Earnings Record*.)

Figure 2

Selection of Food Items Available in Exchange for Food Tokens

Computer Game

All experiments utilized one of two customized computer games—those with actual gains and losses of money utilized SubSearch, a game developed by Hal Miller, Jr., Diego Flores, and Mike Seeley at Brigham Young University, and those with actual gains and losses of food utilized FoodSearch, a version of the original game modified by myself, Nathan Andrews and Thomas Visser.

Game Mechanics. The computer games can be programmed to deliver customized monetary amounts (US $0.05 - $0.25); utilize various types of reinforcement schedules (variable interval, VI, fixed interval, FI, variable ratio, VR, and fixed ratio, FR); utilize various types of punishment schedules (VI, FI, VR, FR); implement various durations of change-over delay (COD); and utilize multiple background colors and condition lengths. Based on the results of a series of 14 pilot experiments conducted prior to the present experiments, optimal parameters for achieving behavioral stability and sensitivity to reinforcers and consequences while simultaneously minimizing time requirements and operating costs, were determined. All experiments in this study used VI schedules, dimes ($0.10), a 2-second change-over delay, 6-minute condition lengths, 3-ply or 6-ply schedules (*ply* indicates the number of experimental conditions in a session) and consisted of 36 to 72 minutes of testing per day with a 10 min break between consecutive sessions. A COD simulated the costs of switching behavior allocation (responding) from one choice alternative to another. Costs for switching between choice alternatives take the form of time, effort, energy, or resources and, although behavior will continue to be governed by its consequences, their effect on future behavior is affected by costs of switching between alternatives. Distinctive background colors are used in each set of choice conditions to signal the distribution of potential rewards and punishments that are available in the choice set. The color, or signal, is known as a discriminative stimulus (S^D), in the presence of which, responses are reinforced or punished on a particular schedule and in the absence of which responses are not reinforced or punished (Powell et al., 2016). Figure 3 and Figure 4 show screenshots of SubSearch and FoodSearch, respectively. The difference in background colors demonstrate two possible S^D. Apart from the use of dimes versus food tokens, graphic interfaces, and on-screen messages referring to coins or food tokens, the two computer games are functionally identical.

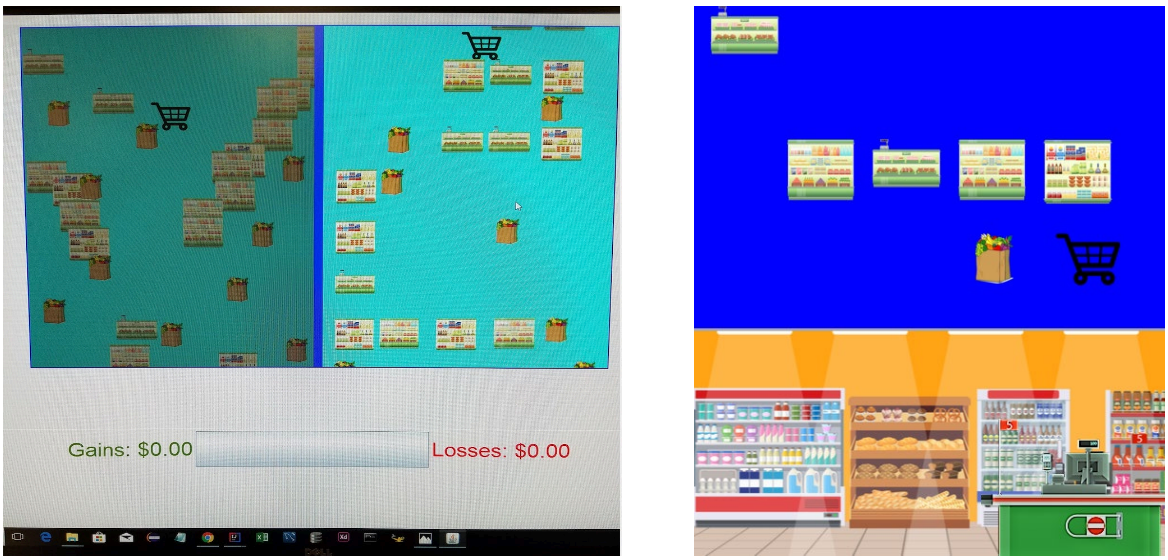
Figure 3

Screenshot of the SubSearch Game

Note. The blue background acts as the S^D in experimental condition A_1 of the SubSearch game. Each experimental condition has a distinct background color. Also pictured on the left side of the image is the seafloor and treasure chest in which participants "deposit" coins to reset the left choice alternative.

Figure 4

Screenshots of the FoodSearch Game



Note. In the image on the left, the turquoise background acts as the S^D in experimental condition B_2 of the FoodSearch game. The image on the right shows the cash register on which participants click to "pay" for their groceries and reset the choice alternative.

Game Interface and Procedures. Both games include a scene that is divided in half vertically. Participants may play the game on either half of the screen and may freely switch between panels (choice alternatives) at any point. When participants move the cursor and click on one panel, the other panel is darkened (see Figures 3 and 4) and all motion paused for two seconds (2-sec COD).

SubSearch provides an underwater ocean scene with underwater barriers around which participants navigate a submarine to retrieve several yellow coin-shaped objects that lay amongst the barriers. The scene in each panel scrolls slowly upward creating the impression of the submarine's descent to the sea floor. When the submarine reaches the sea floor, the participant clicks on a treasure chest to "deposit" their coins causing the scene to refresh at the top of a new panel with a different configuration of barriers and coins. The instructions for the game indicate that some objects are valuable while others are toxic. Depending on the reinforcement and punishment schedules in place, clicking on a coin occasionally results in a gain (+10¢) accompanied by a distinct "cha-ching" sound and an on-screen message, "Collect a coin to continue," and, "After you collect a coin, click here to continue." At this point, participants retrieve a coin from the "source" container, add it to their "gains" container, and click on the "click here to continue," icon, and the game resumes. Occasionally, clicking on a coin results in a loss (-10¢), accompanied by the distinct loss sound and an on-screen message, "Deposit a coin," and, "After you have deposited a coin, click here to continue," whereupon participants select a coin from *their* "gains" container, adds it to their "losses" container, and presses the "click here to continue," icon. A running total of the value of coins gained and lost is displayed at the bottom of the screen (see Figure 3). Participants were informed that the contents of the "source" container are known and that the contents of the "source" container as well as "gains" and "losses" containers are counted after each session and verified with the results of the computer game. At the end of each session, participants exchange their net earnings of coins for the equivalent value of more convenient currency.

FoodSearch is functionally like SubSearch but has few minor differences in the graphic interface. The scene is a grocery store with food shelves and aisles that act as barriers around which participants move a shopping cart to click on and collect bags of groceries (an icon of a brown grocery sack with food visible at the opening) positioned amongst the shelf barriers. The scene scrolls slowly upward creating the sensation that the grocery cart is moving through the aisles. There is a grocery store scene and check-out register at the bottom of the panel and participants click on the cash register to "pay" for their groceries, which causes the scene to refresh at the top of a new panel with a different configuration of food shelf barriers and grocery bags. Depending on the reinforcement and punishment schedules in place, clicking on a grocery bag occasionally results in a gain of one food token, accompanied by the sound of a "crunch," or, someone biting into an apple. Losses are accompanied by the same distinct loss sound as in SubSearch. The on-screen messages are like those in FoodSearch but the word *coin* is replaced with *food token*. The procedure for collecting and relinquishing food tokens is the same as for coins. A running total of food tokens gained and lost is displayed at the bottom of the screen (see Figure 4). At the end of each session, participants exchange their net earnings of food tokens for delicious food items.

In both games, participants are instructed to, "Earn as much as you can." Although the distribution of reinforcers between alternatives is based on pre-programmed schedules and varies with condition, the overall rate of reinforcement, VI 10 sec, is the same in all conditions. Accordingly, participant earnings of money or food are a result of how they play the game—their rate of clicking, their allocation of clicks between choice alternatives, their rate of switching, and their allocation of time spent clicking in each alternative.

Experimental Analysis of Behavior Component. The games utilize behavior analytic procedures embedded within six choice sets. Each choice set consists of a pair of interdependent, concurrent (conc, simultaneously available), variable interval (VI, reinforcement or punishment occurs at unpredictable intervals) schedules of reinforcement or punishment. These procedures provide the context in which the operant learning component takes place—behavioral response patterns to gains or losses of money or food are a function of experience and learning from consequences of past behavior—and are described in detail below. The behavioral responses, or clicks of the mouse, are the behavioral measure used to detect biased decision-making and choice processes.

Recurring Choice. The games simulate recurring, complex choice under conditions of uncertainty and risk. As experienced by decision-makers, decision and choice tasks in life are frequently classes of recurring decisions (decisions that take place in similar environments with similar salient features and outcomes rather than in novel environments with novel alternatives and consequences) rather than discrete choice. Accordingly, the games create a decision environment of recurring choice in which similar choice opportunities are presented to participants hundreds of times.

Concurrent Schedules. Choice necessarily includes a decision-task of selecting one alternative over another alternative or over all other alternatives. The game presents two choice alternatives that are available simultaneously—one on the left side of the computer screen and one on the right, called "concurrent schedules."

Free Choice. As mentioned earlier, choice sets in the game resemble choice as experienced by decision-makers: participants can move freely between choice alternatives at any time as they learn the consequences of allocating their behavior to each. Each switch is accompanied by a 2-second changeover delay (COD) that simulates the cost of switching between choice alternatives. A COD also operates to ensure that, following a switch from one alternative to the other, behavior persists in the latter choice for a brief period (e.g., a few seconds) before a response will produce an available reinforcer. The inclusion of a COD is designed to enhance sensitivity to reinforcement schedules by preventing switches following only one or a few responses.

Schedules of Reinforcement and Punishment. The term *schedule* refers to the configuration of pre-determined parameters that determine the rate and intervals between available reinforcing and punishing consequences of a response in a choice set or alternative within a choice set. The nomenclature consists of the type of interval (VI, FI, VR FR, either fixed or variable amounts of time or numbers of responses, respectively) and the rate, or average interval between consequences (e.g., 10 sec), referred to as the schedule value. The “overall rate of reinforcement” describes the schedule across *both* choice alternatives. The proportion of total consequences scheduled for availability in each choice alternative (left or right side of the screen) is determined with an allocation ratio left: right (L: R), a sort of probability gate, and results in “local rates of reinforcement” schedules, described with the same nomenclature.

Variable Interval Schedules. In all experimental conditions in the present study, the interval between availability of a reinforcing or punishing event is contingent upon the first response after a varying, unpredictable period. Availability of consequences arranged in this way is referred to as a VI schedule. Variable interval schedules are labeled by the average interval of time necessary before a response will result in a consequence. For example, VI 30-sec indicates that a consequence will be available, on average, every 30 seconds, with the actual interval on any discrete choice varying between one and 60 seconds.

Interdependent Schedules. Concurrent VI schedules are frequently used in behavioral choice studies because they produce reliable patterns of responding and are typically designated as conc VI VI schedules. Each notation “VI” refers to one of the schedules of reinforcement operating in the choice alternatives. However, if it is necessary to maintain a pre-determined reinforcement ratio for experimental purposes, concurrent schedules can be problematic: responses to the richer schedule will increase (simultaneously decreasing in the leaner schedule) so that obtained reinforcers become disproportionately more than programmed in the richer schedule.

For example, if the two concurrent schedules are VI 20 sec and VI 60 sec, on average there will be three reinforcers available every minute in the former schedule and one available in the latter, a ratio of 3: 1. As decision-makers learn the ratio, they may neglect responding in the leaner schedule and allocate responses in a 10: 1 ratio, obtaining proportionately more reinforcers on the left than intended. Thus, instead of a 3:1 distribution of responses consistent with the 3:1 distribution of scheduled reinforcers, the 10:1 distribution of responses could produce a distribution of reinforcers widely discrepant from 3:1. In fact, this is what occurred in a previously published studies of behavioral choice involving reinforcers and punishers delivered according to conc VI VI schedules.

To mitigate the inadvertent deviation from scheduled reinforcer distributions when there is a biased response distribution (as is predicted in the reinforcement-plus punishment-conditions), the game utilizes interdependent, conc VI VI schedules of reinforcement. Instead of drawing randomly without replacement from a pair of preexisting lists of intervals with specified means, the scheduling of reinforcers to one side or the other is done by drawing randomly without replacement from a single list and assigning the next scheduled reinforcer to one or the other side of the screen using pre-established probabilities—a sort of probability gate that distributes the reinforcers available in the overall rate of reinforcements in the pre-determined ratio. Interdependent schedules require participants to obtain the scheduled reinforcer on the designated side before the next reinforcer will be assigned. Interdependent schedules ensure that the local rate of reinforcement and punishment in each choice alternative stays consistent with the predetermined schedule making precise measurement of behavioral response patterns to available reinforcement and punishment feasible.

In summary, the SubSearch and FoodSearch games utilize multiple sets of interdependent concurrent variable interval schedules (conc VI VI) of reinforcement and punishment. This design facilitates the systematic variation of the independent variable needed to establish functional relationship with the dependent variable via a reversal experimental design (ABABAB). The design simultaneously maintains local rates of reinforcement and punishment at the predetermined schedules.

Data Collection

Total mouse clicks on the left and right sides of the screen in each condition were recorded and used in formulating response ratios L: R (B_1/B_2). Total obtained reinforcers from the left and right choice alternatives in each condition were recorded and used to formulate reinforcement ratios L: R (R_1/R_2). The summary statistics collected include the time (in seconds) spent responding, the number of clicks, the number of obtained reinforcers, the number of obtained punishers, and the number of switches between choice alternatives.

Experimental Design and Experimental Conditions

Patterns of loss-averse responding as a function of obtained reinforcers and punishers are expected across systematically varied schedules of reinforcement and punishment. Accordingly, each session includes multiple gains-only and gains+punishment experimental conditions (A and B conditions, respectively). Each condition is comprised of two concurrently operating choice alternatives (left and right side of the screen) with unique schedules of reinforcement and punishment. The parameters for each condition can be seen in Table 1 "*Experimental Condition*

Parameters." Reinforcer and punisher ratios, concurrent schedule values, mean available reinforcers per minute and per session, and the scheduled available reinforcer proportion on the left alternative, are shown for each experimental condition (A_1, B_1, A_2, B_2, A_3, B_3). "PUN" indicates a VI punishment schedule superimposed on the left choice reinforcement schedule. All ratios and proportions are presented in terms of left: right choice alternatives.

The number of sessions per day and the interval between testing days was determined by the nature of the experiment's associated research questions. All participants completed 24 sessions in gains-only conditions ($A_1A_2A_3$) and four sessions in gains-only and gains+punishment conditions ($A_1B_1A_2B_2A_3B_3$) to ensure behavioral stability. Four to 16 additional sessions in gains-only and gains+punishment conditions were completed and used for analysis. The number and length of experimental sessions, configuration of experimental conditions, and frequency and total exposure time for each group is summarized in Table 2 on page 132.

Experimental conditions consisted of a pair of choice alternatives, the parameters of which were determined from the results of a series of 14 pilot experiments and are consistent throughout all experiments. All conditions are six minutes in length and use a VI 10 sec overall rate of reinforcement, that is, for every minute of playing time, a reinforcer is available in one of the choice alternatives at an interval that varies around a mean of ten seconds. So, on average, there is a reinforcer available every ten seconds—approximately six reinforcers per minute. The distribution of reinforcers to the left or right choice alternative is determined by the distribution ratio which determines the local rate of reinforcement or punishment operating on the left of right alternative (see Table 1). There are two types of conditions, designated as either A (gains-only schedules), or B (gains+punishment schedules).

A Conditions

The three A conditions used throughout the experiment have the following distribution ratios (L: R): A_1 9: 1; A_2 1: 1; and A_3 1: 9. These ratios translate into the following local rates of reinforcement and average available reinforcers per minute (L:R): A_1 VI 11 sec (5.4 per min): VI 100 sec (.6 per min); A_2 VI 20 sec (3 per min): VI 20 sec (3 per min); and A_3 VI 100 sec (.6 per min): VI 11sec (5.4 per min). For reference, see Table 1.

B Conditions

The three B conditions have identical reinforcement schedules as the A conditions with the corresponding subscript. However, they also have a punishment schedule superimposed on only the L choice alternative resulting in a 1: 0 punishment distribution ratio for all B conditions. The punishment schedule in the L alternative is identical to the local reinforcement schedule that operates there: B_1 VI 11 sec (5.4 per min); B_2 VI 20 sec (3 per min); and B_3 VI 100 sec (.6 per min). For reference, see Table 1.

Table 1

Experimental Condition Parameters

Experimental Condition	A_1	B_1	A_2	B_2	A_3	B_3
Reinforcer Ratio, Punisher Ratio Left: Right	9: 1, 0	9:1, 1:0	1: 1, 0	1: 1, 1: 0	1: 9, 0	1: 9, 1: 0
Concurrent Schedules Left: Right	VI 11-s VI 100-s	VI 11-s (PUN) VI 100-s	VI 20-s VI 20-s	VI 20-s (PUN) VI 20-s	VI 100-s VI 11-s	VI 100-s (PUN) VI 11-s
Mean Reinforcers (+10c or +1 Food Token) Available per Minute Left: Right	5.4: 0.6	5.4: 0.6	3: 3	3: 3	0.6: 5.4	0.6: 5.4
Mean Reinforcers (+10c or +1 Food Token) Available per Condition Left: Right	32.4: 3.6	32.4: 3.6	18: 18	18: 18	3.6: 32.4	3.6: 32.4
Scheduled Reinforcers Left Proportion	.90	.90	.50	.50	.10	.10

Note. Reinforcement-only schedules are operating in A conditions. B conditions have identical reinforcement schedules as the preceding A condition plus a superimposed schedule of punishment (gains+punishment). The overall rate of reinforcement (VI 10 sec) is constant across A and B conditions. That is, on average, a reinforcer is available in either the left or right choice alternative every 10 seconds, or 6 per minute. The side on which each reinforcer is available is determined by the distribution ratio, which determines the local rate of reinforcement operating on that same side.

The logic of the experimental design pits reinforcement-only conditions against reinforcement-plus-punishment conditions to differentiate the effects of gains from those of losses across three distinct reinforcement schedule configurations ($A_1A_2A_3$). Accordingly, a *small-N* reversal design (ABABAB) is implemented by ordering the conditions in each experimental session as follows: $A_1B_1A_2B_2A_3B_3$, where A conditions consist only of reinforcement schedules (gains-only), and B conditions have identical reinforcement schedules with a superimposed punishment schedule (gains+punishment). The design makes possible a pairwise contrast in each condition—the absence versus the presence of punishment—and is the basis for calculating gain-loss asymmetry ratios. If behavioral response patterns systematically demonstrate biased responding in B conditions (gains+punishment) and return to expected response ratios in subsequent A conditions (gains-only), then a functional relationship between punishment and biased response can be demonstrated.

Operant Learning Component

The experimental design provides a decision-making and choice environment based on operant learning—the future probability (response strength) of a behavior is affected by its consequences. In this design, each condition presents a unique three-term contingency—the relationship between a discriminative stimulus, an operant behavior, and a consequence. The discriminative stimulus (the unique background color of the screen in each of the six conditions) signals that specific consequences are available (see Figures 3 and 4). The operant behavior (the class of emitted responses that result in certain consequences) is the ratio of mouse clicks L: R in each condition. The consequence, reinforcing gains of money or food tokens, determine the ratio of obtained reinforcers L: R in each condition. The two ratios (ratio of responses L: R and ratio of obtained reinforcers L: R) obtained in each condition are the dependent and independent variables used as the basis for analysis.

Analysis

As discussed in Chapter 1, prospect theory (Kahneman & Tversky, 1979) was among the most transformative contributions to cognitive psychology and behavioral economics because it provided a mathematical account of the asymmetrical effects of gains and losses on decision-making and choice. The further identification of patterns of biased cognition and several cognitive biases, including loss aversion, were the result. In a series of experiments that utilized hypothetical cognitive-based choice tasks presented in a pairwise configuration, Daniel Kahneman and Amos Tversky demonstrated a 2.25: 1 gain-loss differential—i.e., although a potential gain and a potential loss have the same objective value, the perceived value of the loss is more than twice that of the gain.

Generalized Matching Law

In contrast to cognitive analyses and the use of hypothetical scenarios, this series of experiments employs direct measurement of behavior as decision-makers respond to pairs of concurrent choice alternatives in the context of recurring, complex, uncertain, and risky outcomes. Concurrent operant methods were introduced by B. F. Skinner and have dominated behavioral choice research and produced a large array of mathematical models of choice and decision-making such as Herrnstein's matching relation and the generalized matching relation

(Miller et al., 2017). Baum's (1974) generalized matching relation (Equation 4), is repeated here and is the basis of analysis:

$$\log\left(\frac{B_1}{B_2}\right) = s \log\left(\frac{R_1}{R_2}\right) + \log b \tag{4}$$

Response behavior is modelled according to this relation enabling the comparison of sensitivity and bias estimates (log b) in gains-only and gains+punishment conditions. The comparison of bias estimates is used to calculate gain-loss asymmetry ratios, a quantitative description of individual loss aversion: the factor weighting they attribute to potential loss relative to potential gains.

Operationalization of Loss Aversion

The gain-loss asymmetry ratio indicates participants' subjective valuation of losses relative to gains of the same objective value. In Equation 4, B refers to responses (clicks of the mouse) and *R* refers to the obtained reinforcing consequences of that behavior (gains of money or food tokens). The subscripts 1 and 2 indicate the choice alternative, left or right, respectively, in which the responding occurs, or the reinforcers are obtained. The parameters log *b* and *s* refer to bias and sensitivity, respectively. Sensitivity is the extent to which differences in alternative sources of reinforcement are accessible. Bias is the degree to which one alternative is consistently preferred to the other (Miller, 1976) and results in the allocation of a higher proportion of behavior to that alternative *regardles*s of whether it contains the richer or poorer schedule of reinforcement.

Recall from the discussion on the generalized matching law in Chapter 2 that bias, or preference for one alternative over another irrespective of the rate of reinforcement, is represented when log $b \neq 0$ (Baum, 1974). If log $b = 0$, no bias is evident. If log $b > 0$, there is a bias toward the numerator (choice alternative 1) and if log $b < 0$ there is a bias toward the denominator (choice alternative 2) (Rasmussen & Newland, 2008). In this study, the punished alternative always occurs in the left choice alternative and is represented in the numerator in B conditions. Thus, if log $b < 0$, there is a bias toward the denominator, the right-side unpunished alternative, and expression of loss aversion.

As operationalized in this study, the estimate of log b becomes a proxy for bias, indicating the degree of preference for one alternative over the other in A conditions and the preference, regardless of reinforcement schedule, for the non-punished alternative on the right side in B conditions. Recall that in all B conditions, punishment occurs only on the left side alternative. The measure of bias is understood to be the degree of preference for the right-side alternative, evidenced by the change in distribution of clicks to that side from the previous, corresponding reinforcement-only A condition, *regardless* of the reinforcement schedule operating there.

Based on the generalized matching law, it is expected that the allocation of behavioral responses (ratio of mouse clicks L: R) between the two choice alternatives in each A condition will vary proportionately with the ratio of obtained reinforcers (L: R) from each alternative with some deviation from matching as a function of sensitivity. In the B conditions, however, it is expected that the asymmetrical effect of punishment on the left side alternative will disrupt the proportionate allocation of behavioral responses despite the ratio of obtained reinforcers remaining constant. The degree of disruption will indicate the degree of loss aversion and will be calculated as follows.

Calculating Gain-Loss Asymmetry Ratios

In all conditions, the number of clicks left and clicks right are used to form behavioral response ratios (B_1/B_2, the dependent variable), and the number of obtained reinforcers, left and right, are used to form reinforcement ratios (R_1/R_2, independent variable). A least-squares regression analysis will be applied to the gains-only conditions (A conditions) across all sessions and another regression analysis applied to the gains+punishment conditions (B conditions) across all sessions to produce bias estimates in both types of condition. It is expected that the differences in the bias parameter estimates obtained across gains-only and gains+punishment conditions will provide a reliable and valid measure of the effects of loss against a backdrop of gains-only choice. Once the bias estimates are obtained, gain-loss asymmetry ratios are derived by dividing the anti-log of log b_A by the anti-log of log b_B. Alternatively, ratios can be derived by taking the anti-log of the difference in log b_A and log b_B. Gain-loss asymmetry ratios are interpreted as the weighting of potential losses relative to one gain of the same objective value.

Quantifying Effect of Punishers

In the few studies that have used the generalized matching law to interpret the effects of punishment on choice, modified versions of the equation have been used (Miller et al., 2017, Garnica, 2016; Rasmussen & Newland 2008;). For example, a subtraction model of the equation accounts for the effects of the punishment based on their objective value so that the ratio R_1/R_2 is derived from the net obtained reinforcers:

$$\log\left(\frac{B_1}{B_2}\right) = s\log\left(\frac{R_{1-P2}}{R2-\mathrm{P2}}\right) + \log b \tag{5}$$

where P represents the number of obtained punishers (losses) on that side (see Equation 5). However, the analysis used in this study assumes that the effect of punishment on behavior is *not* an equal but opposite effect as that of reinforcers, but rather, an asymmetrical effect. This analysis will maintain the value of the obtained reinforcer = 1, rather than using a net value. In the present analysis, the original matching law is used (Equation 4) and the effect of the punishers is expected to manifest in the change in B_1/B_2 in A conditions relative to B_1/B_2 in B conditions.

Summary of Analytical Procedures

All participants participated in 24 sessions with gains-only conditions and four sessions with gains-only and gains+punishment conditions to reach behavioral stability. Data from an additional four to 16 sessions in gains-only and gains+punishment conditions were used for calculating gain-loss asymmetry ratios. For each participant, the response and reinforcement ratios from all gains-only conditions are calculated across sessions. The y-intercept (bias) and slope (sensitivity) of least-squares regression lines for gains-only and gains+punishment conditions are obtained by regressing the log of the response ratios (log B_1/B_2) against the log of reinforcement ratios (log R_1/R_2) across all conditions and from multiple sessions. Gain-loss asymmetry ratios are obtained by dividing the anti-log of the bias estimate in gains-only conditions by that in gains+punishment conditions.

Procedures for Experiments with Money

In addition to the procedures described earlier, at the end of each 36-minute session, participants in Experiments 1 and 2 presented their gains (container of dimes earned during the session) to a researcher who verified the earnings with the computer game record and provided more convenient currency in exchange. In each 36-minute session, participant earnings ranged from US$3.00 to US$9.00, average earnings were around US$7.00. The number and timing of sessions depended on the experiment. At the conclusion of all experimental sessions, participants were paid a monetary completion bonus ranging from US$25 to $150. Participants were made aware of the bonus and bonus amount at the time of enrollment. The time requirement varied from two weeks to six months, depending on the experiment, and completion bonuses were graduated accordingly**.**

Procedures for Experiments with Food

All participants in experiments using food as gains and losses were screened for a minimum BMI of 18.5; metabolic or digestive disorders such as hypoglycemia, hyperglycemia, diabetes, pre-diabetes, Crohn's disease, Celiac's disease, etc.; history of eating disorder such as binge eating disorder, bulimia nervosa, or anorexia nervosa; ultra-restrictive diets or weight-loss plans such as gluten-free, Vegan, Keto, etc.; health-threatening food allergies; extreme exercise regimens (more than 2.5-3 hours of high-intensity exercise between the hours of 5 p.m.-11 a.m.); and history of adverse effects from fasting.

Each participant was surveyed on the types of food normally eaten and their preferred foods so that a large, varied inventory of delicious food was provided for session earnings. The regularly stocked food inventory included items such as yogurt, milk, chocolate milk, juice, fresh fruit, cheese, sports drinks, baked good, muffins, ice cream bars, frozen meals (e.g., breakfast burritos, personal pizzas, meat pies, Hot Pockets®), protein bars, granola, oatmeal, jerky, popcorn, candy, chocolates, chips, crackers, etc. See Figure 2 and the FoodSearch Order Sheet and Personal Earnings Record in Appendix A.

Participants completed a food log to verify eating patterns and a normal fasting period (going without food from the last meal of one day to the first meal on the subsequent day). Food items eaten between 5pm-11am were recorded for seven days.

To ensure that hunger levels were at comparable levels and the degree to which food acted as a motivating operation was comparable between participants, a 10–14-hour food deprivation period during the participants' normal fasting period was implemented. Participants were instructed and reminded the day prior to each experimental session to refrain from eating after their last meal at a specified time until their session was completed the following morning. Sessions were scheduled so that fasting periods were a minimum of ten hours and no longer than 14. Verbal confirmation of fasting was obtained prior to each session.

As in the money experiments, the amount of food earned each day was a function of how participants played the game— their rate of clicking, their allocation of clicks between choice alternatives, their rate of switching, and their allocation of time spent clicking in each alternative. At the end of each 36-minute session, participants presented their gains (container of food tokens earned during the session) to a researcher who verified the earnings with the computer game record. Each food token was worth 1 food-point and all food items were clearly labeled with their food token price. Food-point value was based on relative local market prices but manipulated so that tokens were not easily identified as a coin/monetary value. (See Appendix A "FoodSearch Order Sheet and Personal Earnings Record").

A microwave and bistro table with chairs and a plant were provided for participants who wanted to eat immediately, and to-go bags were provided for participants who wanted to eat elsewhere or who had left-overs after eating. After each session, participants were provided with an "order sheet" to track the food-point total of selected items and was required to "spend" all their food-points—a maximum of two food-points (~$0.20 - $0.50 worth of food) was allowed to be "spent" on a subsequent testing day. Several small food items (e.g., mints, gum, chocolates, small oranges) that were easy to carry away and eat later had low food-point values making it easy for participants to use their entire sum of food-points each day and supplement the larger items available for a meal and snacks.

At the conclusion of all experimental sessions, participants were paid a monetary completion bonus, ranging from $20 - $150. They were made aware of the bonus and bonus amount at the time of enrollment. The time requirement varied from one weeks to six months, depending on the experiment, and completion bonuses were graduated accordingly.

Procedures for Experiments with Menstrual Cycle Correlates

Potential participants were initially screened for self-reports of healthy, normal, regularly cycling menstrual cycles for the six months prior to enrollment—they self-reported no missed periods and that cycles were consistently about the same length and occurred at predictable times. If participants had personal records, we collected dates of menses-onset for up to six previous cycles and used them to establish cycle regularity and to calculate average lengths of each participant's menstrual cycle. Inclusion criteria included self-reports of non-use of any type of topical, oral, or internal hormone treatment or birth control, including pills, creams, gels, patches, or intrauterine devices with no plans to begin such treatments in the following six months. They could not be pregnant or planning to become so in the following six months. Each participant agreed to notify researchers if any prescription, medical, or menstrual-related health status changed during the experiment.

Because self-reported cycle lengths and accuracy of recall of menses-onset show considerable measurement error (Small et al., 2007), after participants were enrolled, a minimum of two complete menstrual cycles were observed before testing to ensure continued regularity. All participants were provided with a tracking method—either a calendar and instructions for recording the dates of menses onset, or they could select a mobile app of their choice. A research assistant contacted each participant each week and within a few days of expected menses onset to keep communication active and to remind participants to report their menses onset within 12 hours of starting.

Once participants began experimental sessions, the start and end dates of menses were tracked for the duration of the experiment. After experimental testing was complete, an additional full menstrual cycle was recorded to ensure all cycles during testing were within “regularity” parameters. If at any point during the experimental sessions a woman’s cycle was considered irregular, they continued the full testing regiment but were classified as “irregular” for purposes of analysis.

Assessing Regularity of Participants’ Menstrual Cycles

The menstrual cycle consists of the first day of one menstrual period to the first day of the subsequent menstrual period. The average menstrual cycle lasts about 28 days. One large study reports the mean length is 28.9 days (SD = 3.4) with 95% of cycles between 22 and 36 days and menses lasting from two to seven days (Fehring et al., 2006). The mean length of participants’ cycles will be reported for individuals and cohorts in each experimental group. Among healthy regularly cycling women, there is sizeable normal inter-women and intra-woman variability in the length and phases of the menstrual cycle. Among a cohort of 3,743 girls and women aged 15 to 44, cycle length varied by more than 14 days in 29.3% (Fehring et al., 2006; Münster et al., 1992). Both longitudinal studies and cross-sectional studies reveal that the highest variability occurs in the few years after menstruation begins (menarche) and the two to three years before menopause (Chiazze et al., 1968; Fehring et al., 2006; Treloar et al., 1967).

The variation in the follicular phases (from day one of menses onset until the surge of luteinizing hormone—LH—at ovulation subsides) contributes most to the variation in the cycle phases—follicular, fertile, luteal, and menses phases (Fehring et al., 2006). Based on a 28-day cycle, there is evidence for an approximately six-day fertile period (days on which pregnancy can occur), the day of ovulation, 3-4 days prior and 1-2 days after (Fehring et al., 2006; Wilcox et al., 1995). Ovulation typically occurs around the mid-point of the cycle. Leading up to ovulation there are surges in estrogens and LH and after ovulation the levels begin an immediate decline. On average, the days near ovulation considered the fertile period make up about 20% of any given cycle. Accordingly, to capture at least some part of this point of the cycle, the criteria used to determine regularity is that each cycle length be within 20% of the days of the previous cycle and each cycle thereafter must be within 20% of the average of the previous two cycles.

For example, if a participant has two consecutive cycles before testing that are 28 and 30 days, they are within 7% of each other, the average cycle length is 29 days, the peri-ovulatory point is considered day 14 or 15, and the mid-luteal point is considered day 21 or 22, and the next menses onset is expected to occur at day 29, they are considered "regular," and begin experimental testing. If a third cycle is 31 days, it is within 6% of the average of the previous two cycles and is still considered regular. If, however, the third cycle is 23 days, it is within 21% of the average of the previous two and the cycle is considered irregular for purposes of analysis (although still within the medical criteria for regularly cycling). During testing, at menses-onset, the participant notified the researchers within 12 hours and arrived at the lab within 24 hours to play the experimental game. The participant was scheduled at the expected date for the other two points according to the process described above.

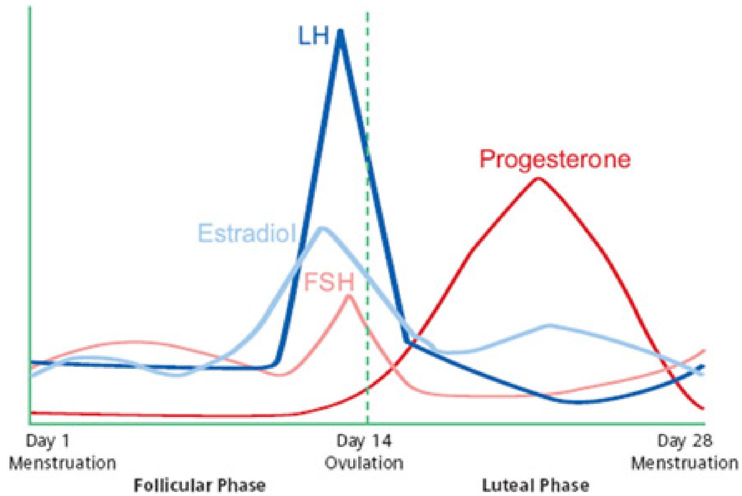
Assessing Menstrual Cycle Phases

Circulating levels of LH, FSH, estradiol, and progesterone follow a cyclical pattern coordinated by the hypothalamic-pituitary-gonadal axis and vary significantly across an individual's cycle as well as between individuals. Inter-women and intra-woman variability mean that group averages may not be useful in identifying cycle phases the further away from the mean an individual's blood volume level for any hormone is. Establishing accurate reference levels of salient hormones for individuals requires the collection of blood samples across several days (Dighe et al., 2005; Stricker et al., 2006). Doing so is both invasive and costly. A few standard methods for determining cycle phase are commonly used, each having benefits and limitations including self-report of menses-onset and varying combinations of blood, saliva, or urinary tests (Allen et al., 2016)

However, because this study does not hypothesize a causal relationship between specific hormone levels and loss-averse behavior, a non-invasive method of phase assessment was utilized that included: an initial self-report of menses-onset dates for up to six previous months; direct tracking of a minimum of two complete menstrual cycles prior to testing; calculating a running average of cycle lengths; and direct tracking of a complete menstrual cycle after experimental testing concluded. Additionally, points of the menstrual cycle that correspond with the three most distinctive hormone level profiles were selected at which points loss-averse responding was measured: (a) menses-onset, at which point LH, estrogens and progesterone are at their lowest and FSH has a secondary peak, (b) peri-ovulatory at the midpoint of the cycle wherein FSH, LH, and estrogens are at their highest levels and progesterone is low, and (c) the mid-luteal point at which progesterone is at its highest level, the estrogens have a secondary peak, and LH and FSH are low. The relative profiles of these hormones are pictured in Figure 5.

Figure 5

Points of the Menstrual Cycle with Distinctive Profiles of Four Key Sex and Pituitary Hormones

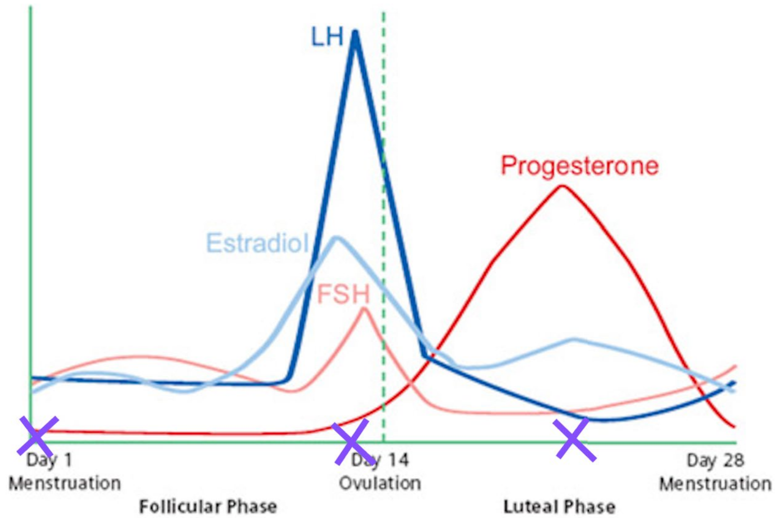


Note. Menses-onset is considered "day one" of a cycle. This figure is based on a 28-day cycle, so the peri-ovulatory point falls on the few days leading up to and the mid-point of the cycle at day 14. The mid-luteal point falls at the three-quarters point of the cycle at day 21.

The rationale for using this method is to detect changes in patterns of loss-averse responding that may vary across the cycle. If there is a relationship with menstrual cycle and loss-averse responding, it is reasonable that the most likely points at which changes in loss-averse responding might be detected will coincide with the most distinctive hormone profiles. Thus, rather than correlating behavior measures with specific hormones or blood serum levels, this study seeks to measure loss aversion across the cycle at day one (menses-onset), the mid-point of the cycle (peri-ovulatory), and ¾ of the way through the cycle (mid-luteal). The points of the cycle used for testing as pictured in Figure 6 and are marked with a large "X."

Figure 6

Points of the Menstrual Cycle at Which Participants are Tested



Yet another rationale for utilizing a non-invasive passage-of-time method, is that invasive, personal, and sometimes uncomfortable biological measurements may act as a motivating operation that could affect the value of gains and losses incurred in the experiment. Further, although participants are aware that menstrual correlates are being investigated, the design of the experimental tasks and the nature of playing the games minimizes social performance or emotional expectation demands surrounding phases of the menstrual cycle. Regular urine samples and blood draws would emphasize the explicit focus on menstrual cycle phases.

Experiment-Specific Design, Methods, and Procedures

This section describes the specific methods and procedures used in each experiment as well as any deviation from the general methods described previously.

Experiments One and Two

Twenty-seven participants (15 women), age 18-25 years, recruited from the student population at Brigham Young University and the local community participated in this study. The experimental groups were configured as follows. In Experiment One, Group 1, N = 8 women, and Group 2, N = 7 men, were reinforced and punished with money (±10¢). In Experiment Two, Group 3, N = 7 women, and Group, 4 N = 5 men, were reinforced and punished with food (±1 food token, exchanged for real food). An additional four participants were excluded from the analysis. The criteria for exclusion included suspected non-conformity to experimental instructions *and* an *r*-squared value less than 0.20 in gains-only conditions of at least one analysis (four or sixteen sessions), indicating a behavioral indifference to reinforcers. The basis for the regression analysis assumes that obtained rewards act as reinforcers and exert an operant effect on future behavior by increasing response strength. One woman was excluded from each Group 1 and 3, and two men were excluded from Group 2. Participant-specific exclusion details, the regression model parameters obtained from each participant, and the effect of the exclusion on the group estimates are included in the notes of Tables 6A, 6B, and 6C. The exclusion of these participants did not affect the relative group level comparisons of mean sensitivity, bias, or r-squared values in gains-only or gains+punishment conditions; nor did the exclusions affect the relative group mean and standard error comparisons of gain-loss asymmetry ratios.

Data collected included total reinforcers (+10¢ or +1 food token) obtained from playing on the left and right choice alternatives of the computer games and total mouse clicks allocated to the left and right choice alternatives. Reinforcement ratios (R_1/R_2, where R_1 is total obtained reinforcers from the left and R_2 is total obtained reinforcers from the right) and response ratios (B_1/B_2, where B_1 is total mouse clicks on the left screen and B_2 is total mouse clicks on the right screen) were calculated in each experimental condition ($A_1B_1A_2B_2A_3B_3$) across all sessions. Table 1 shows the parameters for the experimental conditions in which all participants were tested.

The general methods and procedures for experiments with money were implemented. To ensure behavioral stability, women and men played two 18-minute sessions (gains-only conditions) of SubSearch on 12 consecutive days (24 sessions total) and then two 36-minute sessions (gains-only and gains+punishment conditions) of SubSearch each day for two consecutive days (four sessions total). An additional four sessions along with an additional 12 sessions in gains-only and gains+punishment conditions (16 sessions total) were played every seven to 14 days for up to eight weeks. The data from these 16 sessions was used for analysis. Participants were required to take a 10-min break between the 36-minute sessions each day. These four sessions were used to approximate stability of behavior. Each session of the game consisted of six subconditions in the $A_1B_1A_2B_2A_3B_3$ format. The overall reinforcement rate in all conditions was a VI 10 sec schedule with distributions of 9:1, 1:1, and 1:9 (L: R) in the A conditions, respectively. An identical reinforcement schedule with a schedule of punishment that matched the local rate of reinforcement operating on the left choice alternative was superimposed on the left side in the B conditions. The number and length of experimental sessions, configuration of experimental conditions, and frequency and total exposure time for each group is summarized in Table 2.

Table 2

Experiments One and Two Session Configuration by Experimental Group

		Experimental Sessions to Achieve Behavioral Stability				
Experimental Group	Session Number	Condition Configuration	Condition Length	Session Length	Session Frequency	Daily Exposure
1 & 2	1-24	gains-only (A_1, A_2, A_3)	6-min	18-min	2 per day 12 consecutive days	36-min
3 & 4	1-24	gains-only (A_1, A_2, A_3)	6-min	18-min	4 per day 6 consecutive days	72-min
1, 2, 3 & 4	25-28	gains+punishment ($A_1, B_1, A_2, B_2, A_3, B_3$)	6-min	36-min	2 per day 2 consecutive days	72-mins

		Experimental Sessions for Analysis				
Experimental Group	Session Number	Condition Configuration	Condition Length	Session Length	Session Frequency	Daily Exposure
1 & 2	29-44	gains+punishment ($A_1, B_1, A_2, B_2, A_3, B_3$)	6-min	36-min	2 per day approx. every 7-14 days for 8-12 weeks	72-mins
3 & 4	29-44	gains+punishment ($A_1, B_1, A_2, B_2, A_3, B_3$)	6-min	36-min	2 per day 2 consecutive days approx. every 7-14 days for 4-6 weeks	72-mins

Note. In Experiment One, Group 1, N = 8 women, and Group 2, N = 7 men, were reinforced and punished with (±10¢).

Note. In Experiment Two, Group 3, N = 7 women, and Group 4, N = 5 men, were reinforced and punished with food (±1 food token, exchanged for real food).

Note. Behavioral stability in Groups 3 and 4 was achieved by the same session number (at around session number 15-20) as Groups 1 and 2 despite the difference in daily exposure between the two sets of groups.

Experiments Three and Four

Seventeen participants (12 women) were divided into 3 groups: Groups M1 and M3 each included five women from Groups 1 and 3, respectively, who were determined to be regularly cycling according to strict criteria explained in the method section. Group M2 consisted of the seven men from Group 2 and acted as matched, non-cycling controls to women in Group M1.

Data was collected from the three groups to determine if gain-loss asymmetry ratios in complex, uncertain and risky choice with money and food varied meaningfully with points of the menstrual cycle. Groups M1and M2 played the SubSearch computer game to earn coins (10¢) and Group M3 played the FoodSearch computer game to earn food tokens which were exchanged for real food. Data collected included total reinforcers (+10¢ or +1 food token) obtained from playing on the left and right choice alternatives of the computer games and total mouse clicks allocated to the left and right choice alternatives. Reinforcement ratios (R_1/R_2, where R_1 is total obtained reinforcers from the left and R_2 is total obtained reinforcers from the right) and response ratios (B_1/B_2, where B_1 is total mouse clicks on the left screen and B_2 is total mouse clicks on the right screen) were calculated in each condition ($A_1B_1A_2B_2A_3B_3$) across all sessions. Table 3 shows the configuration of experimental session for each group.

After being screened for cycle regularity and tracking a minimum of two complete menstrual cycles, the general method and procedures for experiments with money, food, and menstrual cycle correlates were implemented. Participants followed the same procedures with the same experimental condition configuration as described in experiments one and tow to reach behavioral stability (sessions 1-24 and 25-28). The last four sessions (29-32) of the initial eight consisting of gains+punishment conditions were used as a baseline reference point. The next 12 sessions (33-44) were completed at each of the three points of their menstrual cycle. Participants in experiment three completed two 36-minutes session at each of the three menstrual cycle points across two full cycles. Participants in experiment four completed two 36-minute sessions on two consecutive days at each of the three points of their menstrual cycle for one complete cycle. In both experiments, the cycle-point at which participants started their testing was counterbalanced, so that women started at three different points. There was no male control group for experiment four.

Table 3

Experiments Three and Four Session-Configuration by Experimental Group

Experimental Group	Session Number	Condition Configuration	Condition Length	Session Length	Session Frequency	Daily Exposure
		Experimental Sessions to Achieve Behavioral Stability				
M1 & M2	1-24	gains-only (A_1, A_2, A_3)	6-min	18-min	2 per day 12 consecutive days	36-min
M3	1-24	gains-only (A_1, A_2, A_3)	6-min	18-min	4 per day 6 consecutive days	72-min
M1, M2, & M3	25-28	gains+punishment ($A_1, B_1, A_2, B_2, A_3, B_3$)	6-min	36-min	2 per day 2 consecutive days	72-mins
		Experimental Sessions for Analysis				
M1, & M2	29-44	gains+punishment ($A_1, B_1, A_2, B_2, A_3, B_3$)	6-min	36-min	2 per day at 3 points of menstrual cycle for 2 complete cycles	72-mins
M3	29-44	gains+punishment ($A_1, B_1, A_2, B_2, A_3, B_3$)	6-min	36-min	2 per day on 2 consecutive days at 3 points of menstrual cycle for 1 complete cycle	72-mins

Note. In Experiment Three, Group M1, N = 5 women, and Group M2, N = 7 men, were reinforced and punished with gains and losses of coins (±10¢).

Note. In Experiment Four, Group M3, N =5 women, was reinforced and punished with gains and losses of food (±1 food token, exchanged for real food).

Note. Behavioral stability in Group M3 was achieved by the same session number (at around session number 15-20) as Groups M1 and M2 despite the difference in daily exposure between the two sets of groups.

Chapter 6: Results

Appendices B, C, D, and E, summarize patterns of behavioral responding for each participant in experiments one and two (Groups 1, 2, 3, and 4), respectively, across the six levels of reinforcement and punishment in the experimental conditions. For ease and clarity of description, each appendix shows the mean proportion of reinforcers (+10¢ *or +1 food token*) obtained and the mean proportion of responses allocated on the *left* choice alternative, leaving the complement on the right side to inference. Mean reinforcers obtained on both the left and right choice alternatives (L: R) and mean responses allocated to both left and right choice alternatives (L: R) in each condition are shown.

Experiments One and Two: Gain-Loss Asymmetry in Choice with Money and Food

This section includes the obtained results from the four experimental groups tested in choice with money (Groups 1 and 2) *and* food (Groups 3 and 4). For clarity, the research questions and hypotheses relevant to these results are repeated here in the same format in which they appeared at the end of Chapter 4: Scholarly Contributions, Research Questions and Hypotheses. The interpretation of the results, as they relate to the specific questions and hypotheses, are discussed in the second half of Chapter 6: Discussion.

Research Question 1

Is loss aversion in recurring, complex, uncertain, and risky choice with real, versus hypothetical, gains and losses of money, a replicable phenomenon of decision-making and choice behavior? How do obtained gain-loss asymmetry ratios compare to those reported in cognitive and behavioral literature?

Hypothesis 1

It is expected that gain-loss asymmetry will be observed in recurring, complex, uncertain, and risky choice with potential gains and losses of real money and that asymmetry estimates will differ meaningfully from estimates reported in the cognitive literature. Neither the magnitude nor direction of the difference is predicted.

Research Question 1a

How do the behavioral effects of losses of money, relative to gains, change over time with repeated learning experience (from four to 16 sessions)?

Hypothesis 1a

It is expected that gain-loss asymmetry estimates will change meaningfully with repeated exposure to unpunished and punished choice with gains and losses of money. Neither the magnitude nor the direction of change is predicted.

Research Question 1b

Does the sex-disaggregated data indicate possible sex/gender differences in gain-loss asymmetry in choice with money? No hypothesis is provided for this exploratory question.

Research Question 2

Is loss aversion a generalizable principle of decision-making and choice across choice domains, e.g., in a non-quantitative choice domain of food? Is gain-loss asymmetry replicable in recurring, complex, uncertain, and risky choice with gains and losses of real food?

Hypothesis 2

It is expected that patterns of loss-averse responding will be apparent in recurring, complex, uncertain, and risky choice with gains and losses of real food.

Research Question 2a

If gain-loss asymmetry is observable in recurring complex, uncertain and risky choice with food, how do asymmetry estimates compare with those reported in choice with real money?

Hypothesis 2a

It is expected that gain-loss asymmetry estimates will be meaningfully higher for decisions with food than in similar conditions with money.

Research Question 2b

How do the behavioral effects of losses of food, relative to gains, change over time with repeated learning experience (from four to 16 sessions)?

Hypothesis 2b

It is expected that gain-loss asymmetry estimates will change meaningfully with repeated exposure to unpunished and punished choice with gains and losses of food. Neither the magnitude nor the direction of change is predicted.

Research Question 2c

When data is collected and reported in a sex-disaggregated fashion, are there any indications of possible sex/gender differences in gain-loss asymmetry in choice with food?

Hypothesis 2c

It is expected that gain-loss asymmetry estimates obtained from recurring, complex, uncertain, and risky choice with gains and losses of real food will be meaningfully higher in women than those obtained from men

Results for Experiments One and Two: Gain-Loss Asymmetry in Choice with Money and Food

Gains-Only Conditions

Gains of money (+10¢) and food tokens (+1 food token) functioned as reinforcers for each group of participants. Table 4 *Mean Proportion Obtained Reinforcers and Response Allocation in Left Choice Alternative Across Experimental Conditions and Sessions*, shows data for participants Groups 1, 2, 3, and 4 in the first, second, third and fourth panels, respectively. Mean proportion of obtained reinforcers (+10¢ for Groups 1 and 2; +1 food token for Groups 3 and 4) on the left (L) side and mean responses allocated to the left choice alternative in each experimental condition are shown for each set of sessions. The first set of rows in each panel depicts the obtained reinforcers and response allocation in the last 12 of 24 sessions consisting of gains-only conditions. The second set of rows in each panel depicts the obtained reinforcers and response allocation in the last four of the initial eight sessions consisting of gains-only and gains+punishment conditions; and the third set of rows shows the same for the last 16 of 20 gains-only and gains+punishment sessions. (Data for the last 16 sessions were not collected for Group 4.)

Table 4 shows that across participants, the mean proportion of behavior allocated to the left choice alternative in gains-only conditions (A_1, A_2, A_3) covaries with the mean proportion of obtained reinforcers on the left side across all sessions. Obtained reinforcers and behavior allocation were highly correlated across all A conditions and sessions: Group 1 r (7) = .99, p = .0001, Group 2 r (6) = .99, p = .00001, Group 3 r (6) = .97, p = .00002, and Group 4 r (4) = .99, p = .0002. The covariation of response allocation and reinforcement value in the A conditions is similar in sessions prior to exposure to punishment (sessions 1-24) and after exposure to punishment (session 25-44) for all groups. The undermatching demonstrated here replicates previous findings on matching in humans (Kollins et al., 1997; Pierce & Epling, 1983; Rasmussen & Newland, 2008) and was expected in the present study due to the complex 3-ply and 6-ply choice architectures in which operant learning took place. Appendices B, C, D, and E include the same information for each individual participant. While coins and food tokens acted as strong, consistent reinforcers for 21participants, reinforcement strength appeared to be weaker and inconsistent for six: JD-2 and SS-3 were indifferent to reinforcement ratios of coins in sessions 13-24 but after exposure to punished choice, response ratios moved in the direction of reinforcement; AF-3 displayed a similar pattern with food tokens; response ratios for RM-3 indicated a low reinforcement strength of food tokens consistently across all sessions; NP-4 responded indifferently to food token reinforcement ratios in conditions A_1 and A_2 across all sessions; and WD-4 was indifferent to food token reinforcement across all conditions in sessions 13-24 and in conditions A_1 and A_2 of session 29-32.

Table 4

Mean Proportion Obtained Reinforcers and Response Allocation in Left Choice Alternative Across Experimental Conditions and Sessions

Experimental Group 1, N = 8 Women Reinforcer (+10¢)							
Experimental Condition		A_1	B_1	A_2	B_2	A_3	B_3
Left Proportion Schedule of Available Reinforcement		.90	.90 PUN	.50	.50 PUN	.10	.10 PUN
Sessions 13-24	Obtained reinforcers mean (SEM) proportion L	.91 (.01)	--	.51 (.01)	--	.10 (.01)	--
	Responses mean (SEM) proportion allocated L	.72 (.04)	--	.50 (.01)	--	.32 (.04)	--
Sessions 29-32	Obtained reinforcers mean (SEM) proportion L	.89 (.01)	.89 (.01)	.51 (.03)	.42 (.03)	.11 (.01)	.10 (.01)
	Responses mean (SEM) proportion allocated L	.76 (.04)	.32 (.06)	.50 (.01)	.26 (.05)	.28 (.03)	.14 (.03)
Sessions 29-44	Obtained reinforcers mean (SEM) proportion L	.90 (.01)	.89 (.01)	.50 (.01)	.48 (.02)	.13 (.01)	.10 (.01)
	Responses mean (SEM) proportion allocated L	.75 (.03)	.32 (.06)	.51 (.01)	.26 (.05)	.30 (.03)	.17 (.04)

Experimental Group 2, N = 7 Men Reinforcer (+10¢)							
Experimental Condition		A_1	B_1	A_2	B_2	A_3	B_3
Left Proportion Available Reinforcement		.90	.90 PUN	.50	.50 PUN	.10	.10 PUN
Sessions 13-24	Obtained reinforcers mean (SEM) proportion L	.90 (.01)	--	.49 (.01)	--	.10 (.01)	--
	Responses mean (SEM) proportion allocated L	.65 (.03)	--	.50 (.01)	--	.36 (.03)	--
Sessions 29-32	Obtained reinforcers mean (SEM) proportion L	.88 (.02)	.92 (.02)	.51 (.02)	.49 (.03)	.09 (.01)	.10 (.01)
	Responses mean (SEM) proportion allocated L	.68 (.03)	.21(.04)	.50 (.01)	.23 (.04)	.31 (.03)	.21 (.06)
Sessions 29-44	Obtained reinforcers mean (SEM) proportion L	.89 (.01)	.90 (.02)	.51 (.01)	.51 (.01)	.10 (.01)	.10 (.01)
	Responses mean (SEM) proportion allocated L	.70 (.02)	.19 (.04)	.50 (.01)	.21 (.03)	.32 (.03)	.19 (.04)

Table 4 (continued)

Experimental Group 3, N = 7 Women
Reinforcer (+1 Food Token)

Experimental Condition Schedule of Available Reinforcement Left Proportion		A_1 .90	B_1 .90 PUN	A_2 .50	B_2 .50 PUN	A_3 .10	B_3 .10 PUN
Sessions 13-24	Obtained reinforcers mean (SEM) proportion L	.90 (.01)	--	.50 (.01)	--	.10 (.01)	--
	Responses mean (SEM) proportion allocated L	.61 (.03)	--	.52 (.01)	--	.39 (.02)	--
Sessions 29-32	Obtained reinforcers mean (SEM) proportion L	.89 (.02)	.79 (.07)	.48 (.05)	.42 (.03)	.12 (.01)	.08 (.01)
	Responses mean (SEM) proportion allocated L	.65 (.05)	.14 (.03)	.51 (.06)	.13 (.03)	.35 (.04)	.11 (.03)
Sessions 29-44	Obtained reinforcers mean (SEM) proportion L	.91 (.01)	.84 (.04)	.49 (.01)	.47 (.02)	.11 (.01)	.09 (.01)
	Responses mean (SEM) proportion allocated L	.72 (.03)	.11 (.03)	.53 (.03)	.12 (.03)	.36 (.03)	.13 (.03)

Experimental Group 4, N = 5 Men
Reinforcer (+1 Food Token)

Experimental Condition Schedule of Available Reinforcement Left Proportion		A_1 .90	B_1 .90 PUN	A_2 .50	B_2 .50 PUN	A_3 .10	B_3 .10 PUN
Sessions 13-24	Obtained reinforcers mean (SEM) proportion L	.90 (.01)	--	.48 (.01)	--	.10 (.01)	--
	Responses mean (SEM) proportion allocated L	.64 (.07)	--	.49 (.01)	--	.34 (.05)	--
Sessions 29-32	Obtained reinforcers mean (SEM) proportion L	.91 (.01)	.86 (.02)	.47(.03)	.40 (.04)	.10 (.02)	.07 (.01)
	Responses mean (SEM) proportion allocated L	.66 (.08)	.33 (.10)	.48 (.02)	.24 (.08)	.30 (.04)	.13(.03)

Reinforcer strength of money and food tokens was maintained after exposure to punished choice. Figure 7 shows individual response allocation (log B_1/B_2) plotted as a function of reinforcement (log R_1/R_2) for gains-only conditions before and after exposure to punishment. Blue data points represent each participant's mean log response ratio as a function of log reinforcement ratio in each of the gains-only conditions for the last four of the initial 24 sessions (before exposure to punished choice). Red data points represent each participant's mean log response ratio as a function of the log reinforcement ratio in gains-only conditions for the first four of 20 total sessions comprised of gains-only and gains+punishment choice. The regression coefficients in the "before exposure" and "after exposure" lines for each group in Figure 7 show that reinforcer strength was maintained and even slightly increased over time and with exposure to punished choice. Response allocation as a function of reinforcement across the three gains-only conditions in the "before exposure" and "after exposure" sessions were: Group 1 before exposure to punishment, y = .41x +.04, r^2 = .71 and after exposure = .49x + .07, r^2 = .72; Group 2 before exposure to punishment, y = 0.25x - 0.01, r^2= .71 and after exposure, y = 0.30x + 0.01, r^2= .82; Group 3 before exposure to punishment, y = 19x -.003, r^2 = .64 and after exposure, y = .27x +.01, r^2 = .53; and Group 4 before exposure to punishment, y = .20x - .04, r^2 = .42 and after exposure, y = .43x -.10, r^2 = .66. After exposure to punishment, response ratios in A conditions returned to and slightly exceeded pre-punished levels in Groups 1, 2, and 3. In relation to reinforcement ratios, response ratios in Group 4 increased dramatically after exposure to punished choice. This demonstrates that, overall, the reinforcer strength was restored to pre-punished levels after exposure to punishment, that the effects of punishment were confined to the gains+punishment conditions, and that punishment did not affect reinforcer strength in subsequent, gains-only conditions.

Summary

Coins and food tokens functioned as reinforcers for all groups: response strength varied with reinforcement level ($A_1A_2A_3$) across all gains-only conditions and produced strong positive correlations. Reinforcer strength of coins and food tokens varied across participants: it was strong for 21 and ranged from weak to moderate for six participants in some conditions. Overall, reinforcer strength was restored to pre-punished levels after exposure to punishment, effects of punishment were confined to the gains+punishment conditions, and punishment did not affect reinforcer strength in subsequent, gains-only conditions.

Figure 7

Individual Mean Log Response Ratio as a Function of Mean Log Reinforcement Ratio in Gains-Only Conditions Before and After Exposure to Punishment

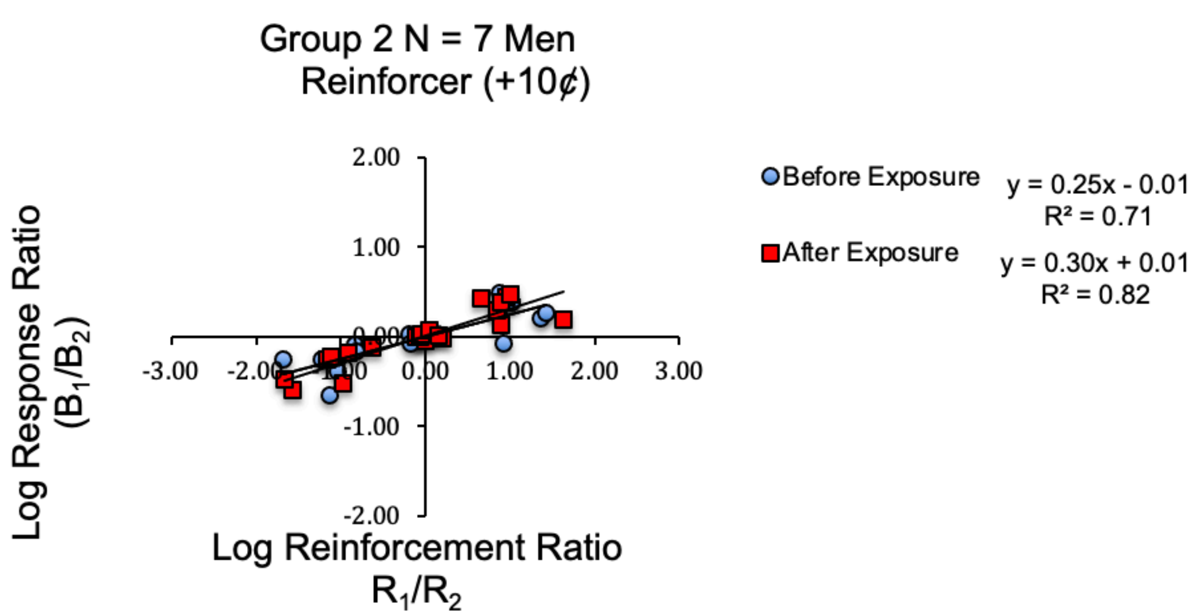
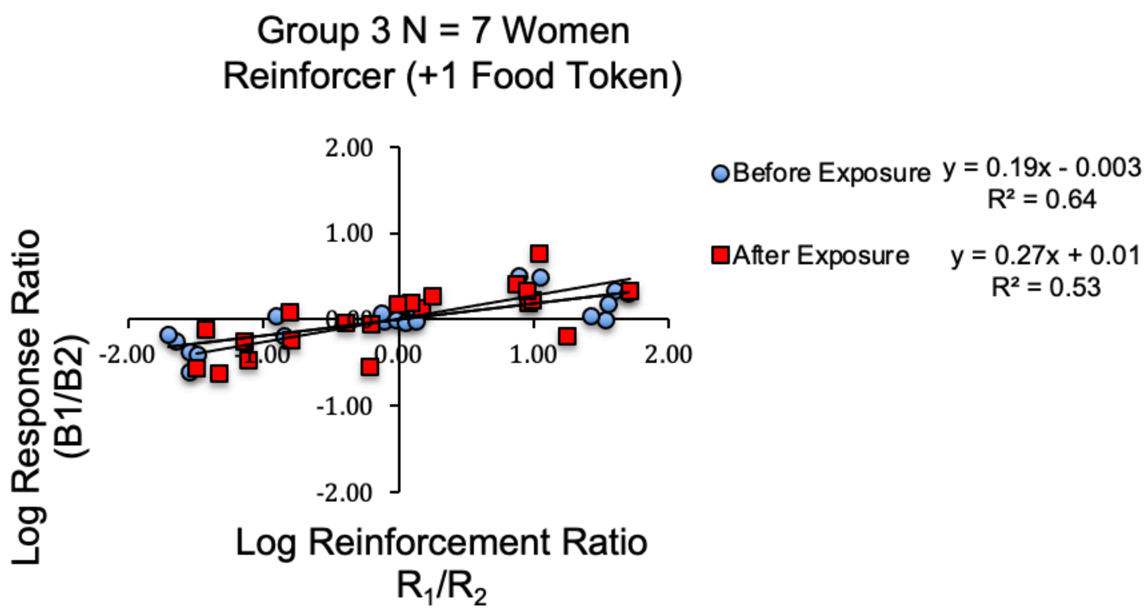
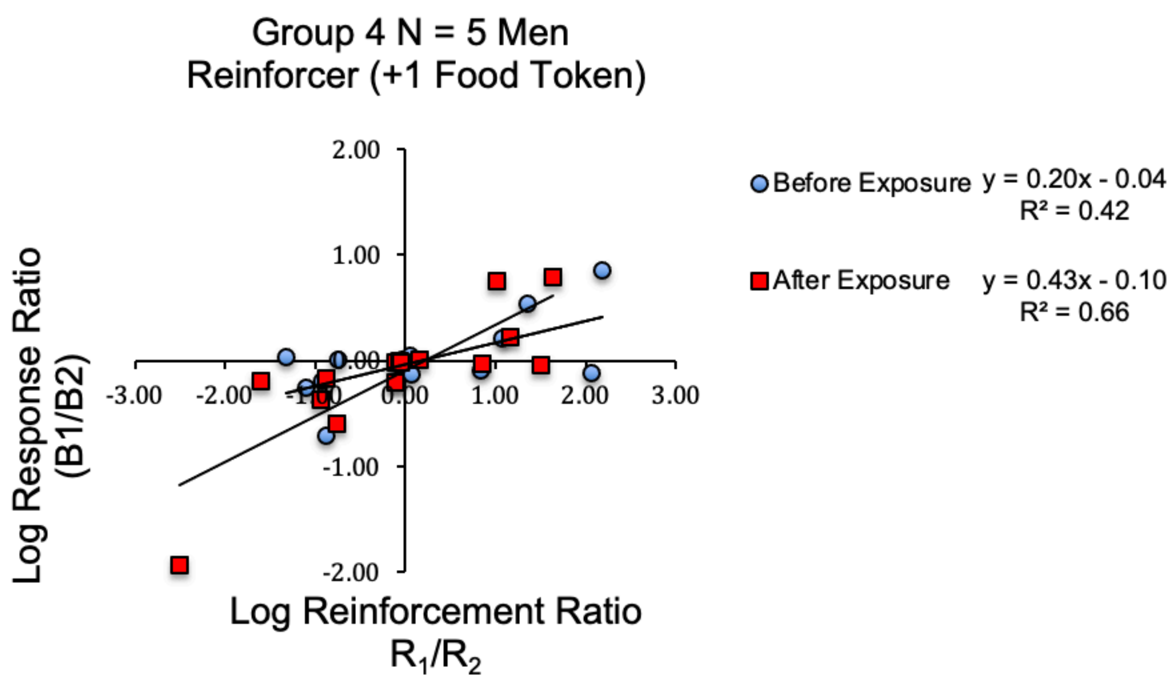


Figure 7 (continued)





Note. Blue circles represent the log response ratio as a function of the log reinforcement ratio for each participant in gains-only conditions (sessions 20-24) before being exposed to punished choice. Red squares represent the log response ratio as a function of the log reinforcement ratio for each participant in gains-only conditions after being exposed to punished choice (29-32).

Sensitivity. Table 5 shows group mean (SEM) sensitivity (slope, *s*) and bias (intercept, log *b*) estimates and r^2 values in gains-only and gains+punishment conditions at four and 16 sessions consisting of gains-only and gains+punishment conditions (A_1, B_1, A_2, B_2, A_3, B_3) are shown. Group Mean (SEM) gain-loss asymmetry ratios are presented in the far-right column and will be introduced later. The first panel shows all estimates for groups reinforced with coins (Groups 1 and 2) and the second panel shows estimates for groups reinforced with food tokens (Groups 3 and 4). The four sessions indicated in the first row of each panel included the last four of eight initial sessions consisting of gains-only and gains+punishment conditions (A_1, B_1, A_2, B_2, A_3, B_3); the 16 sessions indicated in the second row of each panel were the last 16 of 20 total sessions that consisted of gains-only and gains+punishment conditions. Data was not collected for Group 4 participants at 16 sessions.

Estimates of sensitivity (*s*) to coins and food tokens as reinforcers in gains-only conditions indicated undermatching (slopes less than 1) for all groups at both four and 16 sessions. Mean sensitivity estimates for money-reinforced groups at four sessions *s* = .390 (SEM = .07) and at 16 sessions *s* = .347 (SEM = .04). Mean sensitivity estimates for food-reinforced groups at four sessions *s* = .293 (SEM = .06). There is no combined group mean available at 16 sessions for Groups 3 and 4 (data for Group 4 was only collected through session 32).

Table 5

Group Regression Models and Gain-Loss Asymmetry Ratios

4 Sessions	Gains-Only Conditions (A_1, A_2, A_3)			Gains+Punishment Conditions (B_1, B_2, B_3)			
	s	log *b*	r^2	*s*	log *b*	r^2	Gain-loss Asymmetry Ratio (SEM)
Group 1	.512 (.12)	.041 (.04)	.88 (.03)	.205 (.06)	-.675 (.14)	.42 (.11)	8.39 (3.02)
Group 2	.251 (.06)	.003 (.02)	.83 (.03)	.069 (.09)	-.838 (.20)	.17 (.07)	13.73 (6.29)
Mean (SEM)	.390 (.07)	.023 (.02)	.86 (.02)	.142 (.05)	-.751 (.12)	.30 (07)	10.88 (3.29)
16 Sessions							
Group 1	.397 (.07)	.050 (.03)	.75 (.07)	.243 (.03)	-.631 (.16)	.32 (.08)	7.02 (1.93)
Group 2	.290 (.04)	.017 (.01)	.76 (.03)	.058 (.05)	-.842 (.14)	.06 (.03)	10.26 (3.55)
Mean (SEM)	.347 (.04)	.035 (.02)	.75 (.04)	.157 (.03)	-.729 (.11)	.20 (.06)	8.53 (1.92)

Note. Reinforcer was (+10¢) for Groups 1 (N = 8 Women) and 2 (N = 7 Men).

4 Sessions	Gains-Only Conditions (A_1, A_2, A_3)			Gains+Punishment Conditions (B_1, B_2, B_3)			
	s	log *b*	r^2	*s*	log *b*	r^2	Gain-loss Asymmetry Ratio (SEM)
Group 3	.244 (.05)	.020 (.09)	.65 (.09)	.094 (.06)	-1.116 (.20)	.10 (.06)	35.31(21.61)
Group 4	.362 (.13)	-.107 (.10)	.60 (.16)	.331 (.16)	-.947 (.21)	.39 (.04)	12.89 (6.04)
Mean (SEM)	.293 (.06)	-.033 (.06)	.63 (.08)	.192 (.08)	-1.046 (.14)	.22 (06)	25.97(12.85)
16 Sessions							
Group 3	.385 (.11)	.094 (.05)	.57 (.09)	.043 (.05)	-1.190 (.14)	.10 (.02)	26.16 (7.63)

Note. Reinforcer was +1 Food Token for Groups 3 (N = 7 Women) and 4 (N = 5 Men).

Tables 6A, 6B, 6C and 6D *Individual Regression Models and Gain-Loss Asymmetry Ratios,* are a series that summarize sensitivity (*s*) estimates (as well as log *b*, r^2, and gain-loss asymmetry estimates) in gains-only and gains+punishment conditions for each participant after four sessions and 16 sessions for Groups 1, 2, 3, and 4, respectively. Individual mean (SEM) sensitivity (slope, s) and bias (intercept, log b) estimates and r^2 values in gains-only and gains+punishment conditions at four and 16 sessions comprised of gains-only and gains+punishment conditions ($A_1, B_1, A_2, B_2, A_3, B_3$) are shown. Individual gain-loss asymmetry ratios are presented in the far-right column. The top and bottom panels of each table show the estimates for each participant at four and 16 sessions. Across participants, there was a large range of sensitivity to reinforcers in gains-only conditions.

In Group 1, N = 8 women, all participants (except one participant, EZ-1, at four sessions) produced slopes less than 1 (undermatching). There was a large range of sensitivity to reinforcers (+10¢) at four sessions (mean *s* = .512, SEM = .12, range .176 to 1.09). At 16 sessions, the range was smaller and overall sensitivity to reinforcers decreased (mean = .397, SEM = .07, range .116 to .620). Four participants had decreased sensitivity to reinforcers with repeated exposure to non-punished and punished choice, one had an increase, and sensitivity to reinforcers stayed relatively constant for three participants.

In Group 2, N = 7 men, all participants produced slopes less than 1 (undermatching) at four and 16 sessions in gains-only conditions. The range of sensitivity at four sessions was mean *s* = .251, SEM = .06, range .011 to .470. At 16 sessions, the range was smaller and overall sensitivity increased slightly (mean *s* = .290, SEM = .04, range .154 to .433). Only one participant had a notable decrease in sensitivity to reinforcers with repeated exposure to non-punished and punished choice, two participants had increased sensitivity, and sensitivity stayed relatively constant for four participants.

In comparison, Group 2 had a much more restricted range and overall lower values of sensitivity in gains-only conditions at both four and 16 sessions than Group 1. Variability in sensitivity was higher in Group 1 at four sessions—most participants in Group 2 maintained a constant level of sensitivity with repeated exposure compared to Group 1 in which the majority experienced a slight decrease in sensitivity in gains-only conditions.

In Group 3, N = 7 women, all participants produced slopes less than 1 (undermatching) at four and 16 sessions in gains-only conditions. The range of sensitivity at four sessions was mean *s* = .244, SEM = .05, range .091 to .460. At 16 sessions, the range was much larger (primarily because sensitivity in participant EL-3 approached matching at 16 sessions) and overall sensitivity increased (mean *s* = .385, SEM = .11, range .092 to .916). Only one participant had a decrease in sensitivity to reinforcers with repeated exposure to non-punished and punished choice, five participants had increased sensitivity, and sensitivity stayed relatively constant for only 1 participant.

In Group 4, N = 5 men, all participants produced slopes less than 1 (undermatching) at four sessions in gains-only conditions. The range of sensitivity at four sessions was mean *s* = .362, SEM = .13, range .032 to .757. No data was collected for Group 4 at 16 sessions.

In comparison, at 4 sessions, Group 4 had a larger range of values and higher mean sensitivity but also more variance than Group 3 participants. More participants in Group 3 (five of seven) experienced increased sensitivity to reinforcers of food with repeated exposure over 16 sessions than participants in Group 1 (one of eight) did with reinforcers of money.

Bias. Group mean bias values (log *b*) were approximately zero in gains-only conditions for all groups in each choice domain (money and food) at both four and 16 sessions, indicating no group bias for left or right choice alternatives (see Table 5). However, eight participants demonstrated a preference for a particular choice alternative, regardless of the schedule of reinforcement operating there (bias), in gains-only conditions. Two women in Group 1 displayed bias toward the left choice alternative (bias values less than 0) at both four and 16 sessions; no participants in Group 2 demonstrated bias; five of seven women in Group 3 displayed bias—four showed bias toward the left alternative at four sessions (three of these women maintained the bias through 16 sessions) and one woman had a strong bias for the right alternative at 4 sessions but had no bias in gains-only at 16 sessions; and one man in Group 4 had a strong preference for the right alternative at four sessions. See Tables 6A, 6C, and 6D and for individual and group mean bias estimates in gains-only conditions.

R-squared. For women reinforced with coins (Group 1), reinforcement ratios accounted for .71 to .98 (mean = .88, SEM = .03) of the variance in behavior ratios at four sessions and .34 to .95 (mean = .75, SEM = .07) of the variance at 16 sessions. For men reinforced with coins (Group 2), reinforcement ratios accounted for .74 to .93 (mean = .83, SEM = .03) of the variance in behavior ratios at four sessions and .65 to .84 (mean = .76, SEM = .03) of the variance at 16 sessions (see Tables 6A and 6B for reference). In both groups, the proportion of variance in behavior that can be accounted for by reinforcement ratios appears to decrease with repeated exposure to unpunished and punished choice.

For women reinforced with food tokens (Group 3), reinforcement ratios accounted for .10 to .90 (mean = .65, SEM = .10) of the variance in behavior at four sessions and .23 to .89 (mean = .57, SEM = .09) at 16 sessions. For men reinforced with food tokens (Group 4), reinforcement ratios accounted for .05 to .92 (mean = .60, SEM = .16) of the variance in behavior at four sessions (see Tables 6C and 6D for reference). Variance in behavior accounted for by reinforcement ratios in Group 3 decreases somewhat from four to 16 sessions, similarly to that seen in Groups 1 and 2. For both groups reinforced with food tokens, the range of variance in individual response ratios accounted for by reinforcement ratios and between subject variability are much larger at four sessions and somewhat larger at 16 sessions, suggesting that food tokens are relatively less reliable reinforcers than coins.

Summary

All groups produced slopes (*s*) less than one indicating undermatching as expected with humans in complex choice. Group mean sensitivity to reinforcers in gains-only choice with money decreased with repeated exposure from four to 16 sessions and increased in choice with food. At the individual level, participants varied in whether they experienced increased or decreased sensitivity with repeated exposure—most women in choice with food increased in sensitivity at 16 sessions, suggesting that food tokens became increasingly more salient with repeated exposure.

All groups produced bias estimates (log *b*) of zero at four and 16 sessions, but eight of 27 individuals demonstrated bias in gains-only conditions: two participants (both women) of 15 participants in choice with food had a left-side bias, four of 12 participants (all women) in choice with food had a left-side bias and two of 12 (1 woman) in choice with food a had a right-side bias. The bias persists at 16 sessions for all but two. Compared to the other groups and similar behavioral research (Rasmussen & Newland, 2008), the number of women with a bias for the left alternative in choice with food is unusually high. Possible reasons for the bias are given in the discussion section.

Reinforcement ratios had high explanatory power (lowest values $r^2 > .70$) for response ratios in gains-only choice with money at four sessions but this decreases at 16 sessions. Reinforcement ratios had lower explanatory power for response ratios in choice with food at four sessions than those seen in choice with food and the power decreased after 16 sessions. These results suggest that with repeated exposure to complex, uncertain, and risky choice, reinforcement of money and food played less and less a role in response behavior.

Table 6A

Group 1 Individual Regression Model Parameters in Gains-Only and Gains+Punishment Conditions and Gain-loss Asymmetry Ratios at Four Sessions (sessions 29-32)

	Gains-only Conditions (A_1, A_2, A_3)			Gains+punishment Conditions (B_1, B_2, B_3)			Gain-loss Asymmetry Ratio
Participant	*s*	log *b*	r^2	*s*	log *b*	r^2	
CC-1	.408	-.026	.93	.253	-.802	.76	5.97
TH-1	.176	.003	.71	**.258**	-.181	**.74**	1.53
AJ-1	.751	-.076	.91	.124	-1.065	.08	9.74
RD-1	.737	**.221**	.85	.380	-1.054	.65	18.81
FF-1	.251	.071	.86	**.454**	-.307	.62	2.39
GS-1	.495	-0.92	.93	.185	-.545	.40	2.84
EZ-1	1.091	**.220**	.87	-.071	-1.157	.07	23.85
MS-1	.189	.005	.98	.059	-.285	.05	1.95
Mean (SEM)	.512 (.12)	.041 (.04)	.88 (.03)	.205 (.06)	-.675 (.14)	.42 (.11)	8.34 (3.02)

Note. N = 8 women, reinforcer/punisher (±10¢.

Note. Two participants have a bias for the left choice alternative in gains-only conditions. Two participants experience increased sensitivity to reinforcers in gains+punishment conditions. One participant has an increased r^2 value in gains+punishment conditions.

Note. Participant EB-1 was excluded from the analysis due to suspected non-conformity to experimental instructions and producing $r^2 < 0.20$ in gains-only conditions of at least one analysis (at four or sixteen sessions). In gains-only conditions, she allocated behavior left to right 1: 1 across 96 conditions regardless of reinforcement. Demand characteristics, possibly resulting from rumors of the study about loss aversion and optimization, are indicated. In gains-only conditions, $s = -0.02$, log $b = 0.02$, $r^2 = 0.03$. In gains+punishment conditions, $s = -0.02$, log $b = -0.07$, $r^2 = 0.10$. Gain-loss asymmetry = 1.23. With inclusion of her data, group mean gain-loss asymmetry = 7.60 (SEM = 2.78).

Table 6A (continued

Group 1 Individual Regression Model Parameters in Gains-Only and Gains+Punishment Conditions and Gain-loss Asymmetry Ratios at Sixteen Sessions (sessions 29-44)

Participant	Gains-only Conditions (A_1, A_2, A_3)			Gains+punishment Conditions (B_1, B_2, B_3)			Gain-loss Asymmetry Ratio (factor change)
	s	log *b*	r^2	*s*	log *b*	r^2	
CC-1	.420	-.012	.91	.215	-.941	.41	8.50 (+2.53)
TH-1	.116	.080	.34	**.274**	-.184	**.63**	1.84 (+.31)
AJ-1	.509	-.034	.73	.312	-1.096	.31	11.53(+1.79)
RD-1	.583	**.160**	.75	.223	-1.055	.39	16.39(-2.42)
FF-1	.309	.046	.82	**.357**	-.154	.60	1.59 (-.80)
GS-1	.444	-.033	.79	.237	-1.001	.09	9.30 (+6.47)
EZ-1	.620	**.197**	.68	.119	-.576	.06	5.93(-17.93)
MS-1	.174	-.005	.95	**.207**	-.039	.04	1.08 (-.87)
Mean (SEM)	.397 (.07)	.050 (.03)	.75 (.07)	.243 (.03)	-.631 (.16)	.32 (.08)	7.02 (1.93)

Note. N = 8 women, reinforcer/punisher (±10¢).

Note. The factor change in gain-loss asymmetry from four to 16 sessions is indicated with plus and minus signs in parentheses in the far-right column.

Note. Bias for the left choice alternative, increased sensitivity to reinforcers, and an increased r^2 value persisted at 16 sessions for the participants who experienced the same at four sessions.

Note. Participant EB-1 was excluded from the analysis due to suspected non-conformity to experimental instructions and producing $r^2 < 0.20$ in gains-only conditions of at least one analysis (at four or sixteen sessions). In gains+punishment conditions, she consistently allocated more behavior to punished choice resulting in a gain-loss asymmetry ratio < 1.0, indicating that for every increase in reinforcement on the right side, she shifts behavior allocation toward the left, punished choice, regardless of available reinforcement. In gains-only conditions, $s = 0.03$, log $b = 0.01$, $r^2 = 0.06$. In gains+punishment conditions, $s = 0.44$, log b = 0.30, $r^2 = 0.21$. Gain-loss asymmetry = 0.51. With inclusion of her data, group mean gain-loss asymmetry = 6.3 (SEM = 1.84).

Table 6B

Group 2 Individual Regression Model Parameters in Gains-Only and Gains+Punishment Conditions and Gain-loss Asymmetry Ratios at Four Sessions (sessions 29-32)

	Gains-only Conditions (A_1, A_2, A_3)			Gains+punishment Conditions (B_1, B_2, B_3)			
Participant	*s*	log *b*	r^2	*s*	log *b*	r^2	Gain-loss Asymmetry Ratio
JD-2	.190	-.026	.92	-.011	-.352	.01	2.12
ZM-2	.363	.042	.84	-.078	-1.622	.05	46.16
TK-2	.011	-.076	.81	**.233**	-.945	.31	9.05
MT-2	.119	-.024	.74	-.119	-.164	.48	1.38
BT-2	.470	-.007	.93	-.066	-.826	.05	6.59
KG-2	.289	-.039	.78	.016	-.607	.004	4.42
*JR-2	.314	.072	.80	**.510**	-1.349	.27	26.39
Mean (SEM)	.251 (.06)	.003 (.02)	.83 (.03)	.069 (.09)	-.838 (.20)	.17 (.07)	13.73 (6.29)

Note. N = 7 men, reinforcer/punisher (±10¢).

Note. Two participants experience increased sensitivity to reinforcers and one participant produced a negative slope in gains+punishment conditions.

Note. Participants SN-2 and SH-2 were excluded from the analysis due to suspected non-conformity to experimental instructions and producing $r^2 < 0.20$ in gains-only conditions of at least one analysis (at four or sixteen sessions). In gains-only conditions, participant SN-2: s = 0.07, log b = 0.03, r^2 = 0.09; participant SH-2: s = -0.02, log b = 0.01, r^2 = 0.43. In gains+punishment conditions, participant SN-2: s = -0.01, log b = -0.03, r^2 = 0.08, gain-loss asymmetry = 1.14; participant SH-2: s = -0.02, log b = -0.01, r^2 = 0.40, gain-loss asymmetry = 1.06. With inclusion of their data, group mean gain-loss asymmetry = 10.9 (SEM = 5.15).

Table 6B (continued)

Group 2 Individual Regression Model Parameters in Gains-Only and Gains+Punishment Conditions and Gain-loss Asymmetry Ratios at Sixteen Sessions (sessions 29-44)

	Gains-only Conditions (A_1, A_2, A_3)			Gains+punishment Conditions (B_1, B_2, B_3)			Gain-loss Asymmetry Ratio (factor change)
Participant	*s*	log *b*	r^2	*s*	log *b*	r^2	
JD-2	.154	.004	.71	.107	-.301	.14	2.02 (-0.10)
ZM-2	.281	.017	.65	-.033	-1.278	.003	19.72(-26.4)
TK-2	.353	-.016	.82	.117	-.943	.20	8.44 (-0.61)
MT-2	.202	-.032	.79	-.052	-.617	.03	3.84 (+2.46)
BT-2	.433	.032	.80	.018	-.723	.004	5.69 (-0.90)
KG-2	.287	.043	.84	-.030	-.671	.02	5.18 (+0.76)
*JR-2	.319	.071	.71	.277	-1.359	.04	26.95(+0.56)
Mean (SEM)	.290 (.04)	.017 (.01)	.76 (.03)	.058 (.05)	-.842 (.14)	.06 (.03)	10.26 (3.47)

Note. N = 7 men, reinforcer/punisher (±10¢).

Note. The factor change in gain-loss asymmetry from four to 16 sessions is indicated with plus and minus signs in parentheses in the far-right column.

Note. Participants SN-2 and SH-2 were excluded from the analysis due to suspected non-conformity to experimental instructions and producing $r^2 < 0.20$ in gains-only conditions of at least one analysis (at four or sixteen sessions). In gains-only conditions, participant SN-2: s = 0.04, log b = 0.04, r^2 = 0.10; participant SH-2: s = -0.02, log b = 0.004, r^2 = 0.33. In gains+punishment conditions, participant SN-2: s = 0.08, log b = -0.19, r^2 = 0.04, gain-loss asymmetry = 1.68; participant SH-2: s = -0.02, log b = -0.04, r^2 = 0.02, gain-loss asymmetry = 1.10. With inclusion of their data, group mean gain-loss asymmetry = 8.3 (SEM = 3.0).

Table 6C

Group 3 Individual Regression Model Parameters in Gains-Only and Gains+Punishment Conditions and Gain-loss Asymmetry Ratios at Four Sessions (sessions 29-32)

	Gains-only Conditions (A_1, A_2, A_3)			Gains+punishment Conditions (B_1, B_2, B_3)			Gain-loss Asymmetry Ratio
Participant	*s*	log *b*	r^2	*s*	log *b*	r^2	
AR-3	.235	-.003	.74	-.008	-.515	.01	3.30
EL-3	.325	-.042	.78	.090	-.610	.11	3.70
LB-3	.355	**.137**	.77	**.440**	-1.54	.46	47.46
SA-3	.460	**.150**	.90	.025	-.952	.01	12.62
SS-3	.138	**.155**	.58	-.041	-1.005	.04	14.48
AF-3	.103	**-.447**	.10	.020	-1.180	.01	5.41
RM-3	.091	**.192**	.67	**.128**	-2.012	.08	160.20
Mean (SEM)	.244 (.05)	.020 (.09)	.65 (.10)	.094 (.06)	-1.116 (.20)	.42 (.11)	35.31(21.61)

Note. N = 7 women, reinforcer/punisher (±1 food token).

Note. Four participants have a bias for the left choice alternative in gains-only conditions and one participant has a strong bias for the right choice alternative. Two of the participants with a left-choice bias experience increased sensitivity to reinforcers in gains+punishment conditions and demonstrate the most extreme levels of loss aversion.

Note. Participant HM-3 was excluded from the analysis due to suspected non-conformity to experimental instructions and producing $r^2 < 0.20$ in gains-only conditions of at least one analysis (at four or sixteen sessions). In gains-only conditions, $s = 0.11$, log $b = -0.04$, $r^2 = 0.19$. In gains+punishment conditions, $s = 0.07$, log $b = -0.16$, $r^2 = 0.14$. Gain-loss asymmetry = 1.33. With inclusion of her data, group mean gain-loss asymmetry = 31.06 (SEM = 19.2).

Table 6C (continued)

Group 3 Individual Regression Model Parameters in Gains-Only and Gains+Punishment Conditions and Gain-loss Asymmetry Ratios at Sixteen Sessions (sessions 29-44)

Participant	Gains-only Conditions (A_1, A_2, A_3)			Gains+punishment Conditions (B_1, B_2, B_3)			Gain-loss Asymmetry Ratio (factor change)
	s	log *b*	r^2	*s*	log *b*	r^2	
AR-3	.193	.028	.67	.064	-.579	.10	4.05 (+.75)
EL-3	.916	.072	.75	-.100	-.926	.10	10.00(+6.25)
LB-3	.424	**.314**	.55	.221	-1.299	.15	41.08(-6.39)
SA-3	.527	.075	.89	.082	-1.367	.06	27.70(+15.1)
SS-3	.213	**.149**	.65	-.181	-1.014	.18	14.56 (+.08)
AF-3	.330	-.086	.25	.170	-1.453	.11	23.24(+17.8)
RM-3	.092	**.105**	.23	.048	-1.691	.01	62.55(-97.7)
Mean (SEM)	.385 (.11)	.094 (.05)	.57 (.09)	.043 (.05)	-1.19 (.14)	.32 (.02)	26.16 (7.63)

Note. N = 7 women, reinforcer/punisher (±1 food token).

Note. The factor change in gain-loss asymmetry from four to 16 sessions is indicated with plus and minus signs in parentheses in the far-right column.

Note. Three of four participants with a left-choice bias in gains-only conditions retained the bias after repeated exposure. The participant with the right-choice bias at four sessions no longer demonstrates the bias at 16 sessions.

Note. Participant HM-3 was excluded from the analysis due to suspected non-conformity to experimental instructions and producing $r^2 < 0.20$ in gains-only conditions of at least one analysis (at four or sixteen sessions). In gains-only conditions, $s = 0.06$, log $b = -0.25$, $r^2 = 0.05$. In gains+punishment conditions, $s = 0.03$, log $b = -0.36$, $r^2 = 0.01$. Gain-loss asymmetry = 1.30. With inclusion of her data, group mean gain-loss asymmetry = 23.05 (SEM = 7.3).

Table 6D

Group 4 Individual Regression Model Parameters in Gains-Only and Gains+Punishment Conditions and Gain-loss Asymmetry Ratios at Four Sessions (sessions 29-32)

	Gains-only Conditions (A_1, A_2, A_3)			Gains+punishment Conditions (B_1, B_2, B_3)			Gain-loss Asymmetry Ratio
Participant	*s*	log *b*	r^2	*s*	log *b*	r^2	
AD-4	.333	.071	.70	**.484**	-1.40	.28	29.56
NS-4	.184	-.003	.92	-.217	-1.41	.32	25.47
NP-4	.501	**-.481**	.42	**.597**	-.795	.39	2.06
SL-4	.757	-.051	.89	.195	-.317	.44	1.85
WD-4	.032	-.070	.05	**.594**	-.812	**.51**	5.52
Mean (SEM)	.362 (.13)	-.107 (.10)	.60 (.16)	.331 (.16)	-.947 (.21)	.39 (.04)	12.89 (6.04)

Note. N = 5 men, reinforcer/punisher (±1 food token).

Note. Three participants have increased sensitivity in gains+punishment conditions. One participant has a strong bias for the right choice alternative in gains-only conditions. One participant has an increased r^2 value in gains+punishment conditions.

Gains+Punishment Conditions

Losses of money (-10¢) and food tokens (-1 food token) acted as strong punishers for all groups. In Table 2, when behavioral response proportions in the A columns (gains-only conditions) are compared with behavioral response proportions in the B columns (gains+punishment conditions), a clear suppression of response behavior in the left (punished) choice alternative is shown in all B conditions for each group. The large shift in behavior (proportion of responses left) away from the punished alternative in gains+punishment conditions (B_1, B_2, B_3), occurs despite the similarity in proportion of obtained reinforcers to that in the gains-only conditions (A_1, A_2, A_3). This same information for individuals is available in Appendices B, C, D, and E: the mean proportion of reinforcers (+10*¢ or +1 food token*) obtained on the left choice alternative (with mean reinforcers obtained on both the left and right choice alternatives, L: R), and the mean proportion of responses allocated to the left alternative (with mean responses allocated to both left and right choice alternatives, L: R) in each condition are shown. The appendices show that losses of coins and food tokens acted as punishers for every participant. The shift in individual response proportions away from the left side in B conditions and the recovery of responding to pre-punished rates in subsequent A conditions as shown in Appendices B, C, D, and E and Table 4 demonstrate a clear functional relationship between the six levels (A_1, B_1, A_2, B_2, A_3, and B_3) of the independent variable (ratio of obtained reinforcers, R_1/R_2, and ratios of obtained reinforcers with punishment, R_{1pun}/R_2) and the dependent variable (ratio of behavior allocated between left and right choice alternatives, B_1/B_2) for all participants.

Sensitivity: Group 1, N = 8 Women. Participants in Group 1 produced sensitivity values in gains+punishment conditions ranging from -.071 to .454 (mean = .205, SEM = .06) at four sessions, a .60 decrease in mean sensitivity from gains-only conditions. For reference, see the first panel in Table 5 which shows group mean sensitivity, bias, and r-squared values, in gains-only and gains+punishment conditions at four and 16 sessions. The percent decrease in gains+punishment conditions of all estimates is reported. At 16 sessions, sensitivity values in gains+punishment conditions ranged from .119 to .357 (mean = .243, SEM = .03), a .39 decrease in mean sensitivity from gains-only conditions at 16 sessions. (See Table 7, *Group Mean Sensitivity, Bias, and R-squared Values in Gains-Only and Gains+Punishment Conditions and Gain-Loss Asymmetry Values.*) This suggests that women in choice with money recovered some sensitivity to reinforcement in punished choice with repeated exposure (practice).

However, despite the group mean decrease in sensitivity to reinforcement in gains+punishment conditions, paired samples *t* tests showed the difference between sensitivity to reinforcers in gains-only and gains+ punishment conditions was not significant at 4 sessions, $t(7) = 2.01$, $p =$

.08, or at 16 sessions, *t*(7) = 1.96, *p* = .09. Figure 8 *Sensitivity and Bias Estimates in Gains-Only and Gains+Punishment Choice,* shows values for sensitivity (slope, s, left panel) to reinforcement (+10¢) and bias (intercept, log b, right panel) in gains-only (G-O) conditions (blue circles) and gains+punishment (G+P) conditions (red squares) at both 4 and 16 sessions. Dashes represent group means. In the left panel the horizontal line indicates the sensitivity value under perfect matching (s = 1); the horizontal line in the right panel represents the bias value under perfect matching (b = 0).

The left panel in Figure 8 compares sensitivity values (*s)* in gains-only and gains+punishment conditions at four and 16 sessions for all participants. Two of eight participants experience an increase in sensitivity to reinforcers in gains+punished choice at four sessions. They, and one other participant, have increased sensitivity to reinforcers in punished choice at 16 sessions (see Table 6A). Thus, for three of eight participants, sensitivity to reinforcers increases with repeated exposure to punished choice.

Sensitivity: Group 2, N = 7 Men. Participants in Group 2 produced sensitivity values in gains+punishment conditions ranging from -.119 to .510 (mean = .069, SEM = .09) at four sessions, a .72 decrease in mean sensitivity from gains-only conditions. At 16 sessions, sensitivity values in gains+punishment conditions ranged from .052 to .277 (mean = .058, SEM = .05), a .80 decrease in mean sensitivity from gains-only conditions at 16 sessions (see Table 7). Despite the group mean decrease in sensitivity to reinforcement in gains+punishment conditions, paired samples *t* tests showed the difference between sensitivity to reinforcers in gains-only and gains+ punishment conditions was not significant at 4 sessions, *t*(6) = 1.65, *p* = .15, but was significant at 16 sessions, *t*(6) = 4.37, *p* = .004, suggesting that with repeated exposure to punished choice, men in Group 1 had reduced sensitivity to reinforcers of money. One participant (MT-2) produced a negative slope at 4 sessions, indicating that as reinforcer ratios increased on the left side, responding diminished there, and, as reinforcer ratios decreased on the left side (or increased on the right side), responding shifted toward the right side. This demonstrates the disruptive effect of punished choice for this individual. Two participants have increased sensitivity to reinforcement in gains+punishment conditions at 4 sessions but it does not persist through 16 sessions. See the second row in the left panel of Figure 8 to see change in sensitivity from gains-only to gains+punishment at four and 16 sessions.

Sensitivity: Group 3, N = 7 Women. Participants in Group 3 produced sensitivity values in gains+punishment conditions ranging from -.041 to .440 (mean = .094, SEM = .06) at four sessions, a .61 decrease in mean sensitivity from gains-only conditions. At 16 sessions, sensitivity values in gains+punishment conditions ranged from -.181 to .221 (mean = .043, SEM = .05), a .89 decrease in mean sensitivity from gains-only conditions at 16 sessions (see Table 7). Similar to Group 2, paired samples *t* tests showed the difference between sensitivity to reinforcers in gains-only and gains+ punishment conditions was not significant at 4 sessions, $t(6) = 2.21$, $p = .07$, but was significant at 16 sessions, $t(6) = 2.74$, $p = .03$, suggesting that with repeated exposure to punished choice, women in Group 3 had reduced sensitivity to reinforcers of food. Two participants (El-3 and SS-3) produced negative slopes at 16 sessions, indicating that as reinforcer ratios increased on the left side, responding diminished there, and, as reinforcer ratios decreased on the left side (or increased on the right side), responding shifted toward the right side. This demonstrates the disruptive effect of punished choice for these individuals. See the third row in the left panel of Figure 8 to see change in sensitivity from gains-only to gains+punishment at four and 16 sessions.

Sensitivity: Group 4, N = 5 Men. Participants in Group 4 produced sensitivity values in gains+punishment conditions ranging from -.217 to .594 (mean = .331, SEM = .16) at four sessions, a .09 decrease in mean sensitivity from gains-only conditions (see Table 7). However, paired samples *t* tests showed the difference between sensitivity to reinforcers in gains-only and gains+ punishment conditions was not significant at 4 sessions, t (4) = .15, p = .89. One participant (NS-4) produced a negative slope at 4 sessions, indicating that as reinforcer ratios increased on the left side, responding diminished there, and, as reinforcer ratios decreased on the left side (or increased on the right side), responding shifted toward the right side. This demonstrates the disruptive effect of punished choice for this individual. Three of five men experience increased sensitivity to reinforcement in gains+punishment conditions at 4 sessions. Participant WD-4 goes from indifference to reinforcement ratios in gains-only conditions (s = .032) to highly sensitive in punished conditions—it's almost as if the reinforcement ratios of food tokens were meaningless until the potential for losing tokens was experienced. The fourth row in the left panel of Figure 8 depicts the changes in sensitivity from gains-only to gains+punishment.

Table 7

Group Mean Sensitivity, Bias, and R-squared Values in Gains-Only and Gains+Punishment Conditions and Gain-Loss Asymmetry Values

	Sensitivity (s)					
	4 Sessions			16 Sessions		
	Gains-Only	Gains+ Punishment	% Decrease	Gains-Only	Gains+ Punishment	% Decrease
Group 1	.512 (.12)	.205 (.06)	.60	.397 (.07)	.243 (.03)	.39
Group 2	.251 (.06)	.069 (.09)	.72	.290 (.04)	.058 (.05)	.80
Group 3	.244 (.05)	.094 (.06)	.61	.385 (.11)	.043 (.05)	.89
Group 4	.362 (.13)	.331 (.16)	.09	--	--	--

	Bias (log b)					
	4 Sessions			16 Sessions		
	Gains-Only	Gains+ Punishment	Decrease in log b	Gains-Only	Gains+ Punishment	Decrease in log b
Group 1	.041 (.04)	-.675 (.14)	.72	.050 (.03)	-.631 (.16)	.68
Group 2	.003 (.02)	-.838 (.20)	.84	.017 (.01)	-.842 (.14)	.86
Group 3	.020 (.09)	-1.12 (.20)	1.14	.094 (.05)	-1.19(.14)	1.28
Group 4	-.107 (.10)	-.947 (.21)	.84	--	--	--

	R-squared					
	4 Sessions			16 Sessions		
	Gains-Only	Gains+ Punishment	Decrease in log b	Gains-Only	Gains+ Punishment	Decrease in log b
Group 1	.880 (.03)	.420 (.11)	.52	.747 (.07)	.315 (.08)	.58
Group 2	.831 (.03)	.167 (.07)	.80	.761 (.03)	.063 (.03)	.92
Group 3	.650 (.09)	.102 (06)	.84	.570 (.09)	.100 (.02)	.82
Group 4	.598 (.16)	.389 (.04)	.36	--	--	--

	Gain-Loss Asymmetry Ratios					
	4 Sessions			16 Sessions		
	Gains-Loss Asymmetry Ratio	SEM	Range	Gains-Loss Asymmetry Ratio	SEM	Range
Group 1	8.39	3.02	1.53 – 23.85	7.02	1.93	1.08 – 16.39
Group 2	13.73	6.29	1.12 – 46.16	10.26	3.55	2.02 – 26.95
Group 3	35.31	21.61	3.30 – 160.2	26.16	7.63	4.05 – 62.06
Group 4	12.89	6.04	1.85 – 29.56	--	--	--

Note. The first panel shows group mean (SEM) sensitivity (s) values, the second panel shows group mean (SEM) bias values (log b), and the third panel shows group mean (SEM) r-squared values in gains-only and gains+punishment conditions at four and 16 sessions. The percent decrease in sensitivity and r-squared and the unit decrease in log b are reported. The fourth panel shows group mean (SEM) and range of gain-loss asymmetry ratios.

Bias: Group 1. Bias estimates (log *b*) in gains+punished choice for women in Group 1 ranged from -1.157 to -0.181 (mean = -.675, SEM =.14) at four sessions and -1.096 to -.039 (mean = -.631, SEM = .16) at 16 sessions. See Table 7 for a summary. The mean difference between bias values in gains-only and gains+punishment conditions was .72 at four and .68 at 16 sessions (see Table 7). Paired sample *t* tests showed significant differences between the bias parameters in gains-only and gains+punishment conditions at both four sessions, $t(7) = 4.41$, $p = .003$, and at 16 sessions, $t(7) = 4.30$, $p = .004$. The right-hand column in Figure 8 compares group mean and individual bias estimates (log *b*) between gains-only and gains+punished choice at four and 16 sessions. Each data point in Figure 8 represents one participant.

Figures 9, 10, 11, and 12 depict log response ratios (log B_1/B_2) on the y-axis plotted against the log reinforcement ratios (log R_1/R_2) on the x-axis in gains-only conditions and gains+punishment conditions for participants in each group after four sessions of 6-ply gains-only and gains+punishment conditions (A_1, B_1, A_2, B_2, A_3, B_3). Response ratios in gains-only conditions are indicated by blue circles and red squares in gains+punishment conditions. Tables 6A, 6B, 6C, and 6D show the parameters for the regression models in gains-only and gains+punishment conditions at both four sessions (top panel) and 16 sessions (bottom panel) for each participant in each group.

Figure 9 shows the following for Group 1: log response ratios plotted as a function of the log reinforcement ratios in gains-only conditions (A1, A2, and A3) and gains+punishment conditions (B1, B2, and B3) for each participant at four sessions (similar graphs are not shown at 16 sessions, but the regression model parameters are shown in Table 6A). After four sessions, intercepts (log *b*) of the gains-plus punishment regression lines lie cleanly below those in the gain-loss regression lines (difference in intercepts >.28, or gain-loss asymmetry ratio > 1.9) for 7/8 participants. Gains-only regression lines are marked with blue circles and gains+punishment regression lines are marked with red squares. The exception is TH-1. After 16 sessions, gains-plus punishment regression lines lie cleanly below gains-only regression lines for only 5/8 participants. The exceptions are TH-1, FF-1, and MS-1. This suggests that for some, the effect of loss on responding in punished choice is attenuated somewhat over time.

There is consistency between the regression lines for all participants at four and for 5/8 participants at 16 sessions. The exceptions are GdS-1, who exhibits increased right-side bias relative to gains-only choice, and EZ-1, and MS-1, who decrease in right-side bias. (Interestingly, these three participants were the only ones excluded from the menstrual analysis due to cycle length irregularity greater than 20%.) Thus, for a minority, bias is not constant with repeated exposure to punished choice. Another paired samples *t* test on the mean difference in bias values at gains+punishment conditions relative to gains-only from four to 16 sessions revealed that the behavioral bias toward the unpunished alternative did not change significantly with repeated exposure to punished choice, $t(7) = .30$, $p = .78$. Thus, it is unclear to what degree repeated exposure played a role in the participant's fluctuation in bias.

Bias: Group 2. Bias estimates (log *b*) in gains+punished choice for men in Group 2 ranged from -1.622 to -0.164 (mean = -.838, SEM = .20) at four sessions and -1.359 to -.301 (mean = -.842, SEM = .14) at 16 sessions. See Table 6 for a summary. The mean difference between bias values in gains-only and gains+punishment conditions was .84 at four and .86 at 16 sessions (see Table 6). Paired sample *t* tests showed significant differences between the bias parameters in gains-only and gains+punishment conditions at both four sessions, $t(6) = 4.05$, $p =$

.01, and at 16 sessions, $t(6) = 5.75$, $p = .001$. The right-hand column in Figure 8 compares group mean and individual bias estimates (log *b*) between gains-only and gains+punished choice at four and 16 sessions. Each data point in Figure 8 represents one participant.

Figure 10 shows that after four sessions, the gains-plus punishment regression lines lie cleanly below those in the gain-loss regression lines (difference in intercepts >.28, or gain-loss asymmetry ratio > 1.9) for 6/7 participants in Group 2. The exception is MT-2. After 16 sessions, gains-plus punishment regression lines lie cleanly below gains-only regression lines for all 7/7 participants. There is consistency between the regression lines for all participants at four and for 5/7 at 16 sessions. The exceptions are MT-2, who exhibits increased right-side bias relative to gains-only choice, and ZM-1, who decreases in right-side bias. Thus, as with Group 1, for a minority of participants, repeated exposure to punished choice can either increase or decrease bias. Similar to Group 1, paired samples *t* tests on the mean difference bias values at four and 16 sessions revealed that the behavioral bias toward the unpunished alternative did not change significantly with repeated exposure to punished choice, $t(6) = -.20$, p = .85. Thus, it is unclear to what degree repeated exposure played a role in the participant's fluctuation in bias.

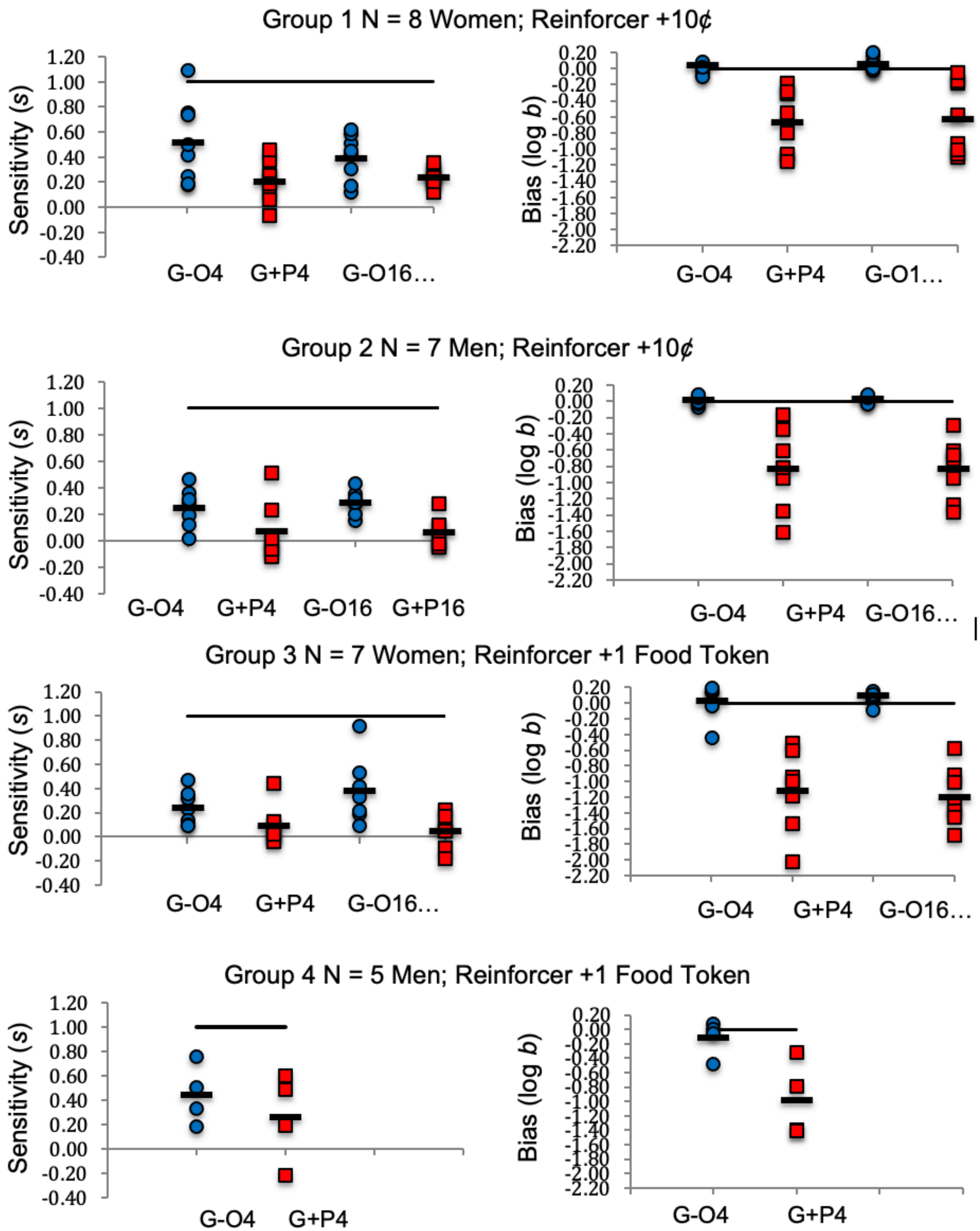
Bias: Group 3. Bias estimates (log *b*) in gains+punished choice for women in Group 3 ranged from -2.012 to -0.515 (mean = -1.116, SEM = .20) at four sessions and -1.691to -.578 (mean = -1.190, SEM = .14) at 16 sessions. See Table 6 for a summary. The mean difference between bias values in gains-only and gains+punishment conditions was 1.14 at four and 1.28 at 16 sessions (see Table 6). Paired sample *t* tests showed significant differences between the bias parameters in gains-only and gains+punishment conditions at both four sessions, $t(6) = 4.85$, $p = .002$, and at 16 sessions, $t(6) = 8.5$, $p = .0001$. The right-hand column in Figure 8 compares group mean and individual bias estimates (log *b*) between gains-only and gains+punished choice at four and 16 sessions. Each data point in Figure 8 represents one participant.

Figure 11 shows that after four and 16 sessions, the gains-plus punishment regression lines lie cleanly below those in the gain-loss regression lines (difference in intercepts >.28, or gain-loss asymmetry ratio > 1.9) for all participants in Group 3. There is consistency between the regression lines for all participants at four and for 4/7 at 16 sessions. The exceptions are El-3, and AF-3, who exhibits increased right-side bias relative to gains-only choice, and RM-3, who decreases in right-side bias. Thus, as with Group 1 and 2, for a minority of participants, repeated exposure to punished choice can either increase or decrease bias. As with Groups 1 and 2, paired samples *t* tests on the mean difference bias values at four and 16 sessions revealed that the behavioral bias toward the unpunished alternative did not change significantly with repeated exposure to punished choice, $t(6) = -1.11$, p = .31. It is unclear to what degree repeated exposure played a role in the participant's fluctuation in bias.

Bias: Group 4. Bias estimates (log *b)* in gains+punished choice for men in Group 4 ranged from -1.410 to -0.317 (mean = -.947, SEM = .21) at four sessions. The mean difference between bias values in gains-only and gains+punishment conditions was .84 at four sessions (see Table 6**).** Paired sample *t* tests showed significant differences between the bias parameters in gains-only and gains+punishment conditions at four sessions, $t(4) = 8.50$, $p = .0001$. Each data point in Figure 2 represents one participant. Figure 12 shows that after four sessions, the gains-plus punishment regression lines lie cleanly below those in the gain-loss regression lines (difference in intercepts >.28, or gain-loss asymmetry ratio > 1.9) for 4/5 participants. The exception is SL-4. No data was collected for Group 4 participant to compare change in bias in gains+punished conditions at 16 session versus four.

Figure 8

Sensitivity and Bias Estimates in Gains-Only (G-O) *and Gains+Punishment* (G+P) *Choice*



Note. Blue circles and red squares depict estimates in gains-only and gains+punished choice, respectively. Dashes represent group means. The horizontal line in the left panel indicates sensitivity under perfect matching (s = 1); the horizontal line in the right panel represents the bias under perfect matching (b = 0).

R-squared: **Group 1**. R-squared values decreased in punished conditions across four and 16 sessions for all but one participant (TH-1). The percent decrease (.52 and .58 at four and 16 sessions, respectively) was relatively constant despite repeated exposure to risky choice. Reinforcement ratios accounted for .05 to .76 (mean = .42, SEM .11) of the variance in behavior ratios at four sessions and .04 to .63 (mean = .32, SEM .08) of the variance at 16 sessions. For comparison of individual r^2 values in gains-only conditions and gains+punishment conditions, refer to Table 5.

R-squared: **Group 2**. R-squared values decreased in punished conditions across four and 16 sessions for all participants. The percent decrease (.80 and .92 at four and 16 sessions, respectively) was relatively constant despite repeated exposure to risky choice. Reinforcement ratios accounted for .004 to .48 (mean = .17, SEM .07) of the variance in behavior ratios at four sessions and .004 to .14 (mean = .06, SEM .03) of the variance at 16 sessions. For comparison of r^2 values in gains-only conditions and gains+punishment conditions, refer to Table 5. The range of r^2 values at both four and 16 sessions was much more restricted than that seen in Group 1 and the percent decrease in explanatory power of the reinforcement ratios was almost two times greater than that seen in Group 1 women.

R-squared: **Group 3**. R-squared values decreased in punished conditions across four and 16 sessions for all participants. The percent decrease (.84 and .82 at four and 16 sessions, respectively) was relatively constant despite repeated exposure to risky choice. Reinforcement ratios accounted for .01 to .46 (mean = .420, SEM .11) of the variance in behavior ratios at four sessions and .01 to .18 (mean = .32, SEM .02) of the variance at 16 sessions. The reduced range of r^2 at 16 sessions and the high level of disruption from four to 16 sessions is a similar pattern to that seen in Group 2. For comparison of r^2 values in gains-only conditions and gains+punishment conditions, refer to Table 5.

R-squared: **Group 4**. R-squared values decreased in punished conditions across four sessions for all but one participant (WD-4). The percent decrease in r^2 was .36 at four sessions. Reinforcement ratios accounted for .28 to .51 (mean = .39, SEM .04) of the variance in behavior ratios at four sessions. For comparison of r^2 values in gains-only conditions and gains+punishment conditions, refer to Table 5. So, although the percent decrease in r^2 stays relatively constant at four and 16 sessions within each group, Groups 1 and 4 see a much smaller decrease than Groups 2 and 3 at both points. All groups tested at 16 sessions (Groups 1, 2, and 3) have a more restricted and lower range of r^2 values with lower variance at 16 sessions compared to four, suggesting that with repeated exposure to punished choice, for all but two participants, the portion of variance in response ratios that can be accounted for by reinforcement ratios decreases in both women and men in choice with money and in women in choice with food.

Summary

All participants produced slopes (log *b*) less than 1 (indicative of undermatching) in the gains+punishment conditions. Significant decreases in group mean average sensitivity estimates in gains+punishment conditions relative to gains-only, only occurred after 16 sessions for men with money and women with food. Otherwise, there was variability between participants in the degree of disruption in sensitivity in punished choice. Women in choice with money appeared to recover some of the decreased sensitivity after 16 sessions while the other participants saw further reductions. A large minority of participants (33% of participants in choice with money and 42% of participants in choice with food) experienced increased sensitivity to reinforcers in punished choice.

For all participants, bias estimates in gains+punishment conditions are negative and significantly different at both four and 16 sessions indicating a strong preference for the right, non-punished alternative regardless of reinforcement schedules operating in the left or right alternatives. Mean group bias estimates appear to persist over time from four to 16 sessions—there are no significant group differences in change in bias due to repeated exposure. However, four of 22 participants have an increased right-side bias at 16 sessions relative to four sessions, and four have a decreased bias. Participants in each group who displayed no bias or a bias towards the left choice alternative in gains-only conditions, experienced a steep preference reversal away from the left, punished choice in gains+punishment conditions. Bias estimates for participants who exhibited a bias toward the right choice in gains-only conditions increased markedly. The variability in individual bias estimates increases dramatically in gains+punished choice relative to estimates from gains-only choice for all groups demonstrating the disruptive effects of potential loss.

The amount of variance in individual response ratios accounted for by reinforcement ratios decreased in punished choice at both four and 16 sessions for all groups. Additionally, the variance in individual response ratios at 16 sessions decreased relative to four sessions for all groups suggesting that with repeated exposure to punished choice, the reinforcing function of reinforcement ratios accounts for less variance in responding behavior (see Table 5).

Figure 9

Group 1 (N = 8 Women, Reinforcer +10¢) Log Response Ratios as a Function of Log Reinforcement Ratios in Gains-Only and Gains+Punishment Conditions

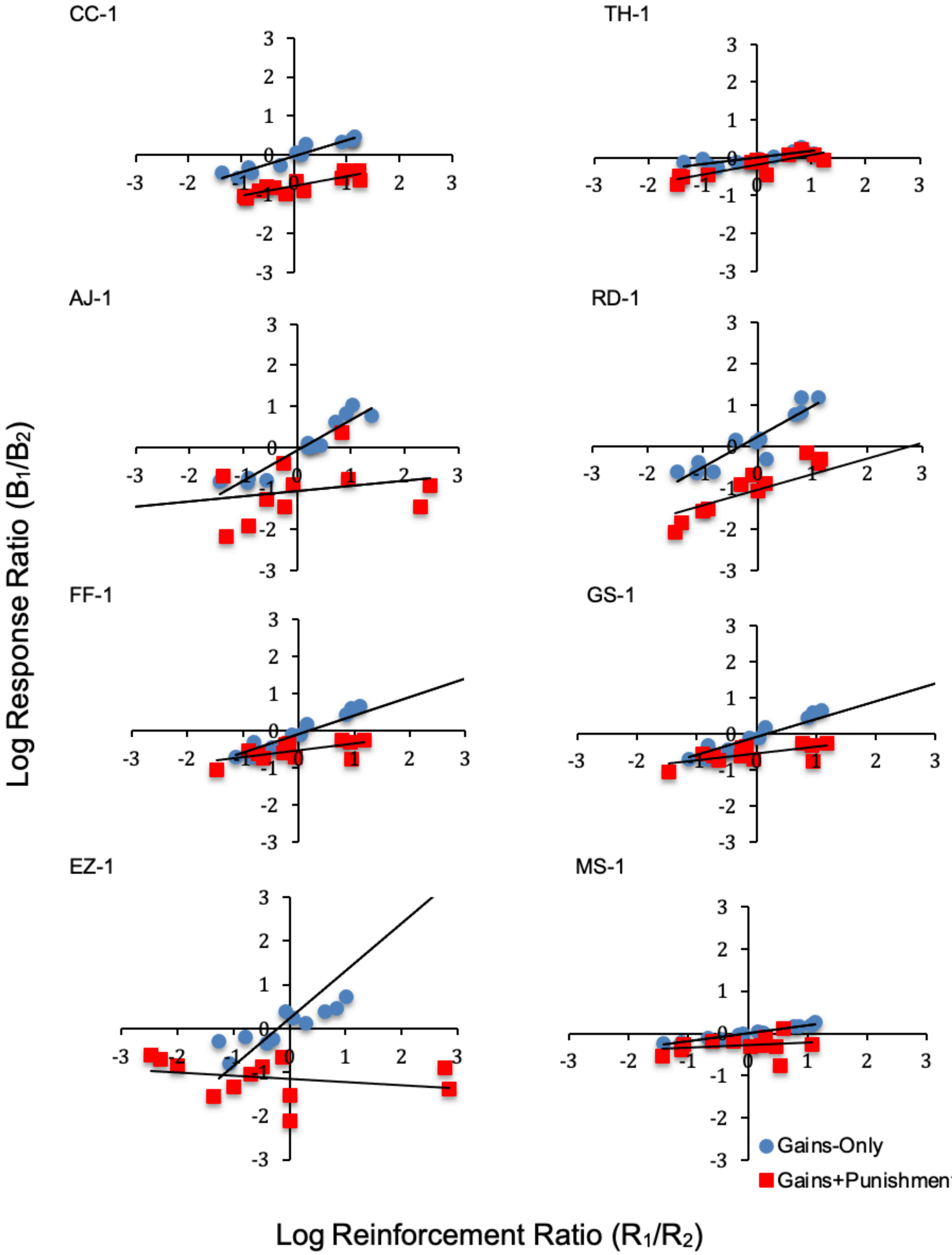


Figure 10

Group 2 (N = 7 Men, Reinforcer +10¢) Log Response Ratios as a Function of Log Reinforcement Ratios in Gains-Only and Gains+Punishment Conditions

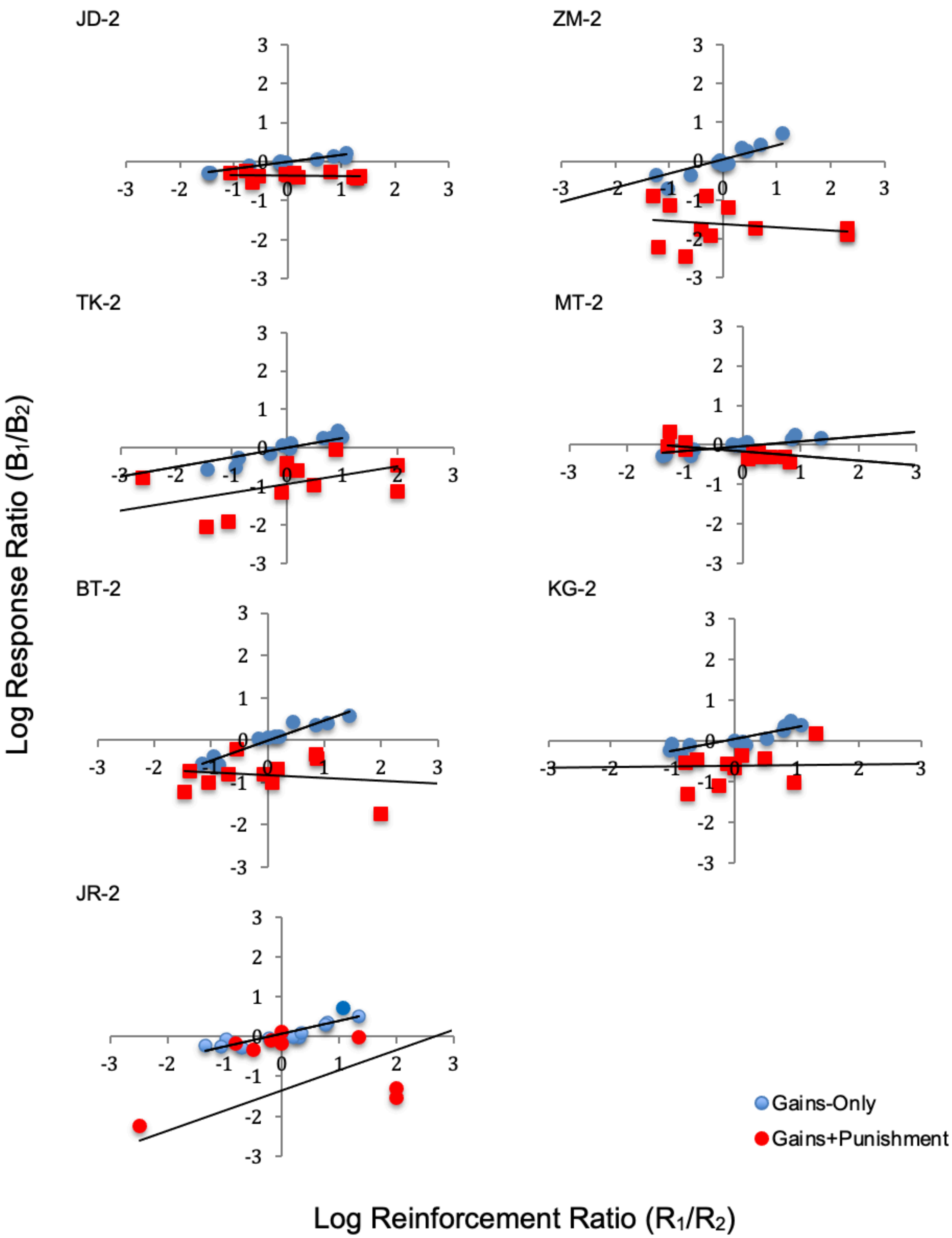


Figure 11

Group 3 (N = 7 Women, Reinforcer +1 Food Token) Log Response Ratios as a Function of Log Reinforcement Ratios in Gains-Only and Gains+Punishment Conditions

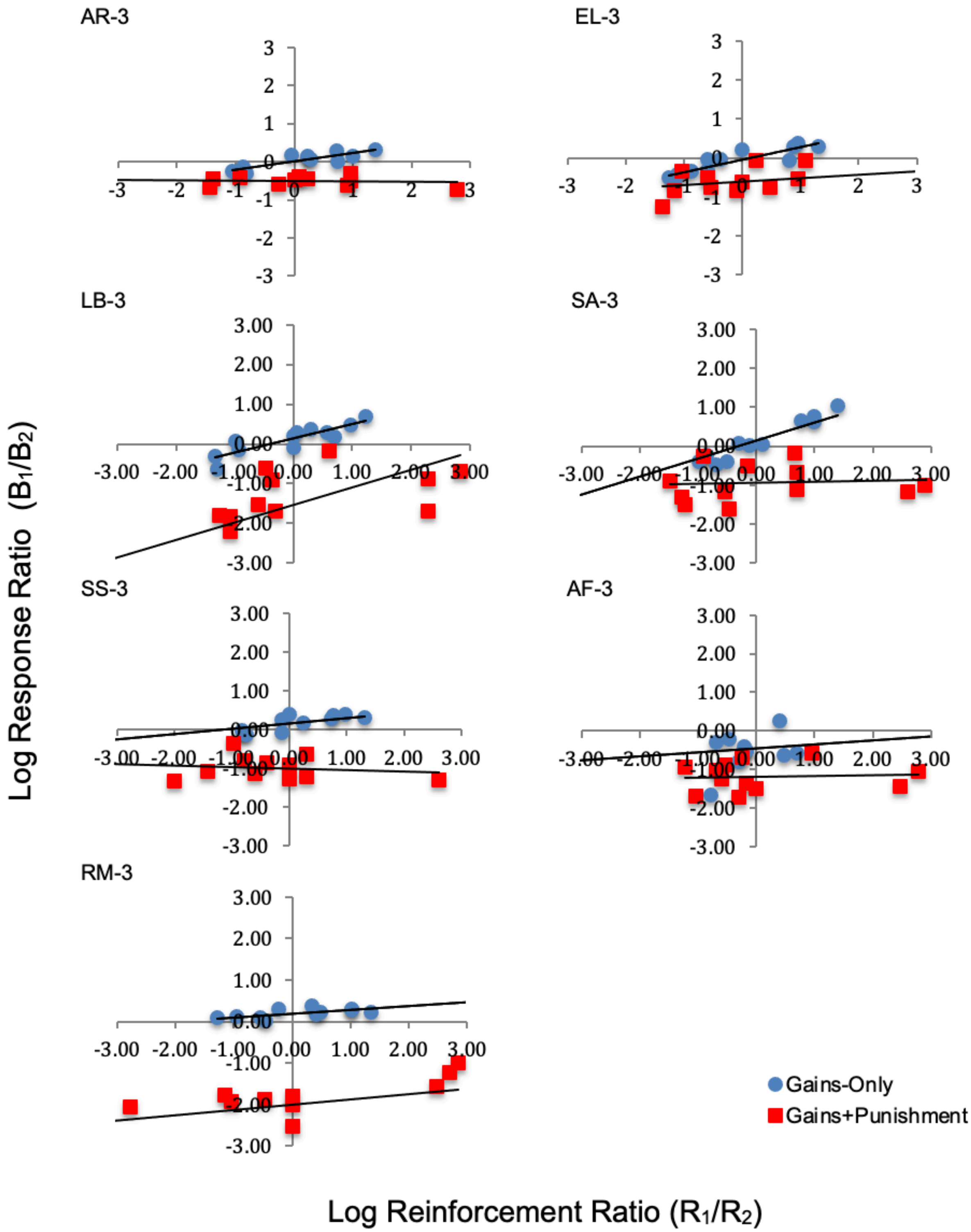
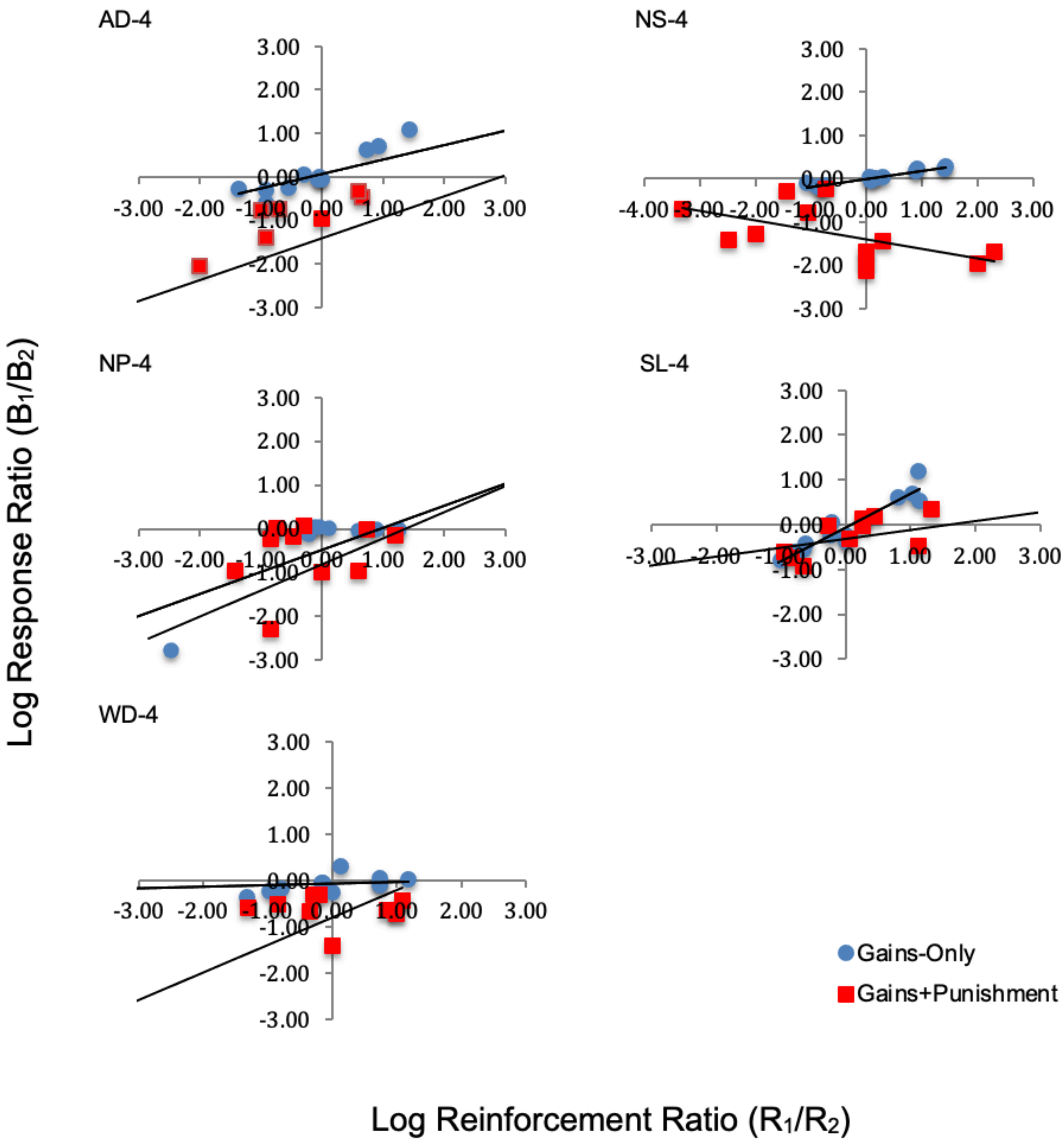


Figure 12

Group 4 (N = 5 Men, Reinforcer +1 Food Token) Response Ratios as a Function of Log Reinforcement Ratios in Gains-Only and Gains+Punishment Conditions



Gain-Loss Asymmetry Ratios

Gain-loss asymmetry ratios were calculated by dividing the anti-log of the bias estimate in the gains-only conditions (log b_A) by the anti-log of the bias estimate from the gains+punishment conditions (log b_B). Alternatively, asymmetry ratios can be derived by taking the anti-log of the difference between the bias estimates (intercepts) of the regression lines of the gains-only and gains+punishment conditions. The asymmetry ratio is interpreted as the number of monetary gains (+10¢) or food tokens (+1 food token) necessary for an equivalent effect on behavior allocation (B_1/B_2) as one loss (-10¢ or -1food token). A gain-loss asymmetry ratio indicates the degree (factor) to which a loss of 10¢ or 1 food token is more punishing than a gain of the same is reinforcing. A gain-loss asymmetry ratio is, in effect, a precise measure of the effect-size of punishment on behavior allocation towards available reinforcers of coins and food tokens.

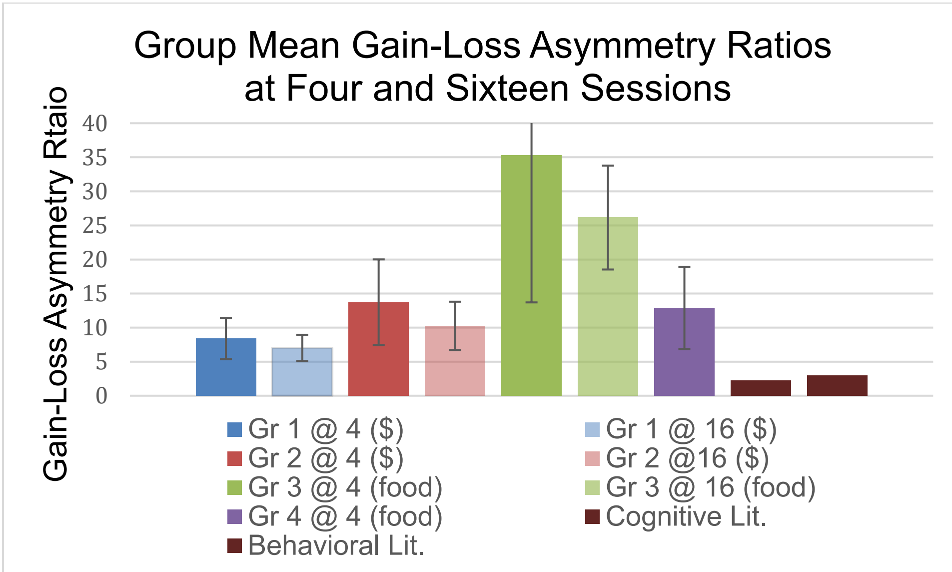
Individual and group mean gain-loss asymmetry ratios at four and 16 sessions appear in the far-right column of Tables 6A, 6B, 6C and 6D. In the present study, group mean gain-loss asymmetry ratios at four sessions were: Group 1 women reinforced with coins, mean = 8.39, SEM = 3.02, range = 1.53 to 23.85; Group 2 men reinforced with coins, mean = 13.73, SEM = 6.29, range = 2.12 to 46.16; Group 3 women reinforced with food tokens, mean = 35.3, SEM =35.3, SEM = 21.61, range = 3.30 to 160; and Group 4 men reinforced with food tokens, mean = 12.89, SEM = 6.04, range 1.85 to 29.56. A summary of group mean gain-loss asymmetry values, SEM, and ranges appear in the last panel of Table 7. Figure 13 is a graphical summary of group mean gain-loss asymmetry ratios and within group variance at four and 16 sessions. Each column represents the mean gain-loss asymmetry ratio for each group at either four or 16 sessions. Error bars (SEM) represent within group variance. The two columns on the far right show mean gain-loss asymmetry ratios reported in the cognitive literature and a similar behavioral study. All groups displayed high variance in response to loss, but women in choice with food had extreme variance in response to potential loss.

With repeated exposure to risky choice from four to 16 sessions, the group mean asymmetry value, group variance, and the range of values decreased. The mean gain-loss asymmetry ratios (SEM) and range of values at 16 sessions were all smaller relative to those at four sessions for all groups tested at 16 sessions (Groups 1, 2, and 3): Group 1 women reinforced with coins, mean = 7.02, SEM = 1.93, range = 1.08 to 16.39; Group 2 men reinforced with coins, mean = 10.26, SEM = 3.55, range = 2.02 to 26.95; and Group 3 women reinforced with food tokens, mean = 26.16, SEM = 7.63, range = 4.60 – 62.06. For reference, see the bottom panel of Table 5, *Gain-Loss Asymmetry Ratios*, and the far-right column at 16 sessions in Tables 6A, 6B, and 6C. All groups had a large decrease in variance at 16 sessions, and women in Group 3 had an extreme decrease although their variance remains higher than the other groups.

Despite the decrease in asymmetry estimates at 16 sessions for all groups, an individual level analysis shows that participants do not follow a similar pattern of change in gain-loss asymmetry with repeated exposure to punished choice. Tables 6A, 6B, and 6C show the factor-decrease or increase in gain-loss asymmetry for individuals at 16 sessions, relative to four, in parentheses in the gain-loss asymmetry column. In Group 1, the asymmetrical effects of punishment increase with repeated exposure for three women, decrease for four and stay about the same for one. In Group 2, the asymmetry with repeated exposure increases for two men, decreases for three, and stays about the same for two. In Group 3, gain-loss asymmetry increases for four women, decreases for two, and stays about the same for one.

Figure 13

Group Mean Gain-Loss Asymmetry Ratios at Four and Sixteen Sessions



In summary, individual differences in response to gains and losses were pronounced in all groups but the asymmetrical behavioral effects of loss were almost ubiquitous. Of the 27 participants tested at four sessions, only one displayed a near-symmetrical effect (gain-loss ratio < 1.5). Three participants had gain-loss asymmetry ratios of 1.5 to 2, four had ratios of 2 to 3, and 19 had ratios greater than 3. Of the 22 participants who also tested through 16 sessions, only one had a near-symmetrical effect (gain-loss ratio < 1.5). Two participants had gain-loss asymmetry ratios of 1.5 to 2, one had a ratio of 2 to 3, and 18 had ratios greater than 3. Of note, all seven women in Group 3 had ratios greater than 3 at both four and 16 sessions.

The behavioral effects of loss outweighed that of gains in choice domains of both money and food, in both women and men participants, and with repeated exposure. For 19 of 27 participants at four sessions and for 18 of 22 participants at 16 sessions, gain-loss asymmetry ratios were markedly higher than those reported in cognitive literature (Kahneman and Tversky, 1979, reported estimates around 2.25) and in behavioral literature (Rasmussen and Newland, 2008, reported estimates around 3). Group 1 and 2 participants in monetary choice produced gain-loss asymmetry ratios 3 to 6 times greater than those reported in cognitive literature and 2 to 5 times greater than those reported in similar behavioral studies. Group 3 and 4 participants in choice with food produced asymmetry ratios 6 to 16 times greater than those reported in the cognitive literature with money and 4 to 12 times greater than those reported in a similar behavioral study with money.

Group mean asymmetry ratios, variance, and ranges all decreased with repeated exposure to punished choice: nine of 22 participants experienced a decrease in loss aversion, nine experienced an increase, and four experienced no change.

Experiments Three and Four: Menstrual Cycle Correlates and Gain-Loss Asymmetry in Choice with Money and Food

Data was collected from three groups of participants (Groups M1, M2, and M3) to determine if gain-loss asymmetry ratios in complex, uncertain and risky choice with money and food varied meaningfully with points of the menstrual cycle. Groups M1and M2 played the SubSearch computer game to earn coins (10¢) and Group M3 played the FoodSearch computer game to earn food tokens which were exchanged for real food. Groups M1 and M3 each included five women from Groups 1 and 3, respectively, who were determined to be regularly cycling according to strict criteria explained in the method section. Group M2 consisted of the seven men from Group 2 and acted as matched, non-cycling controls to women in Group M1. Data collected included total reinforcers (+10¢ or +1 food token) obtained from playing on the left and right choice alternatives of the computer games and total mouse clicks allocated to the left and right choice alternatives. Reinforcement ratios (R_1/R_2, where R_1 is total obtained reinforcers from the left and R_2 is total obtained reinforcers from the right) and response ratios (B_1/B_2, where B_1 is total mouse clicks on the left screen and B_2 is total mouse clicks on the right screen) were calculated in each condition ($A_1B_1A_2B_2A_3B_3$) across all sessions. The configuration of experimental conditions was identical to the conditions in the previous experiments (see Table 1). Table 2 in Chapter 5 shows the configuration of experimental session for each group.

For clarity, the research questions and hypotheses relevant to the results obtained from Groups M1, M2, and M3, are repeated here in the same format in which they appeared at the end of Chapter 4: Scholarly Contributions, Research Questions and Hypotheses. The interpretation of the results, as they relate to the specific questions and hypotheses, are discussed in the second half of Chapter 6: Discussion.

Research Question 3

Do gain-loss asymmetry estimates observed in recurring, complex, uncertain, and risky choice with money vary with three points of the menstrual cycle?

Hypothesis 3

It is not expected that gain-loss asymmetry estimates in choice with money will vary meaningfully with points of the menstrual cycle.

Research Questions 4

Do gain-loss asymmetry estimates observed in recurring, complex, uncertain, and risky choice with food vary with three points of the menstrual cycle?

Hypothesis 4

It is expected that gain-loss asymmetry estimates in choice with food will vary meaningfully with points of the menstrual cycle.

Two analyses were conducted to determine if gain-loss asymmetry ratios in complex, uncertain, and risky choice with money (coins) and food (food tokens exchanged for food) varied meaningfully with different points of the menstrual cycle (menses-onset, peri-ovulatory, and mid-luteal). The first was a group-level analysis in which reinforcement ratios and response ratios (R1/R2 and B1/B2 from the six experimental conditions described in Table 1) from each participant at a baseline measure and each cycle point were aggregated and used to calculate gain-loss asymmetry at each of those points. The purpose of the group-level analysis was to determine whether there were obvious patterns of change and obvious value differences in gain-loss asymmetry ratios across baseline and cycle points between regularly cycling women and non-cycling men in choice with money and between regularly cycling women in choice with money and choice with food. The second analysis used reinforcement ratios and response ratios from each participant at each cycle point to calculate gain-loss asymmetry ratios for that person at a baseline measure and at the three menstrual cycle points.

Experiments Three and Four: Menstrual Cycle Correlates and Gain-Loss Asymmetry in Choice with Money and Food

Group-Level Analysis: Menstrual Cycle Correlates and Gain-Loss Asymmetry

The components of the regression models (*s*: sensitivity-slope; log *b*: bias-intercept, and r^2 values) for gains-only and gains+punishment conditions for each group at baseline, menses-onset, peri-ovulatory, and mid-luteal points of the cycle are shown in Table 8, *Group Regression Models for Groups M1, M2, and M3* shows log response ratios as a function of log reinforcement ratios.) Sensitivity (slope, s) and bias (intercept, log b) estimates and r^2 values in gains-only and gains+punishment conditions are shown at baseline and three points of the menstrual cycle. Gain-loss asymmetry ratios for baseline and each point of the cycle are presented in the far-right column. Reinforcer type is shown in parentheses next to the group description.

Gains-Only Conditions.

Sensitivity. Aggregated sensitivity values were less than 1 at all points of the cycle for all groups, indicating undermatching as seen in the previous analyses. The range and average sensitivity value across cycle points is higher in Groups M1 and M3 (women in choice with money and food) than in M2 (men in choice with money) and variability across cycle points about the same between groups: Group M1 *s* range = .339 to .530, mean = .407, SEM = .05; Group M2 *s* range = .247 to .398, mean = .291, SEM = .04; Group M3 *s* range = .305 to .558, mean = .431, SEM = .05.

Bias. Aggregated bias values (log *b*) are clustered around zero at baseline and each cycle point in Groups M1 and M2 and at baseline and the peri-ovulatory point in Group M3. There is a left-choice bias at menses-onset and mid-luteal points in Group M3 (see Table 8).

R-squared. Reinforcement ratios accounted for similar proportions of response ratios across cycle points and across groups. Group M1 r^2 range = .58 to .74; Group M2 r^2 range = .60 to .83; and Group M3 r^2 range = .49 to .67. There is no detectable pattern of variation in r^2 at cycle points within Groups.

Summary. At the group-level of analysis, in complex, uncertain and *riskless* choice, sensitivity to reinforcers has low variability across menstrual cycle points in all groups. There is no bias at any cycle point for any group but a left-choice bias at menses-onset and mid-luteal points for Group M3. There is no detectable difference in r^2 estimates across cycle points for any group.

Gains+Punishment Conditions.

Sensitivity. Aggregated sensitivity values were sharply diminished in gains+punishment conditions relative to gains-only at all cycle points and for all groups. The variance in sensitivity across cycle points is relatively constant between groups. Group M1 *s* range = .199 to .196, mean = .258, SEM = .02; Group M2 *s* range = -.014 to .126, SEM = .03; Group M3 *s* range = -.048 to .014, SEM = .04 (see Table 8). Figure 14 shows log response ratios (*y*-axis) plotted as a function of log reinforcement ratios (*x*-axis) for each group at baseline and each cycle point. The graphs are organized into columns by group (reinforcer/punisher type is indicated in parentheses) and into rows by cycle point. Each round data point represents a single participant's log response ratio as function of log reinforcement ratio in gains-only conditions and square data points represent the same in gains+punishment conditions. Except in Group M1 at the mid-luteal point, there is an observable flattening in gains+punishment slopes for all groups at all points demonstrating the generally disruptive effect of loss on sensitivity to reinforcers. At baseline, there is relative consistency between the regression lines for all three groups. There is consistency between the regression lines for Group M1 at all cycle points indicating low variability in the decrease in sensitivity in gains+punishment conditions from baseline across cycle points. Relative to baseline, Groups M2 and M3 produce more divergent gains+punishment slopes at the three cycle points (although the pattern of decrease in sensitivity across points is dissimilar) indicating that group M1 experiences the least disruption in sensitivity to reinforcers at cycle points. (This is a similar finding in the individual analysis in section 1, but the variability there was too high to conclude a group difference.) The percent decrease in sensitivity ranges from .13 to .45 in Group M1, .52 to 1.06 in Group M2, and .57 to 1.09 with Group M3 (see Table 8). No groups share a similar pattern of disruption between baseline and cycle points as another. Group M1 (regularly cycling women) and Group M2 (non-cycling men) have a similar pattern of disruption at cycle points (greatest disruption at menses-onset and the lowest at mid-luteal) but disruption in sensitivity across cycle points in Group M3 does not have a similar pattern. This suggests that at the group level, sensitivity to reinforcers in punished choice does vary but not with the points of the menstrual cycle.

Bias. Gains+punishment regression lines lie cleanly below that of gains-only lines at all cycle points for all groups (see Figure 14) and bias parameters at all points and for all groups are negative (see Table 8), indicating a large shift in bias toward the right, unpunished alternative. Despite a bias towards the left choice alternative in gains-only conditions, there is a large preference reversal for the right choice at menses-onset and mid-luteal points for Group M3. Between groups, Group M3 has the largest difference in intercepts at each cycle point, followed by Group M2 and then M1 (see Figure 14).

R-squared. There is a sharp decrease in the percentage of response ratios that can be explained by reinforcement ratios in gains+punishment conditions at all points of the cycle for all groups. The percent decrease in r^2 is relatively constant across cycle points within each group. Group M1 maintains the highest r^2 values (r^2 range = .15 to .24) while values in groups M2 and M3 decrease to approximately zero at all cycle points (see Table 8).

Summary. At the group-level of analysis, sensitivity to reinforcers is severely disrupted in punished choice at all cycle points for all groups. Group M1 experiences relatively consistent disruption in sensitivity across cycle points relative to baseline while Groups M2 and M3 see more disruption across cycle points relative to baseline. The inclusion of Group M2 in this finding suggests that something other than the menstrual cycle is contributing to the decrease in sensitivity at cycle points relative to baseline. Within each group, variance in sensitivity across cycle points is low. There is a large shift in bias toward the right, unpunished alternative at all cycle points for all groups with Group M3 participants experiencing the largest shifts across cycle points followed by Group M2. *R*-squared estimates decrease in punished choice at all cycle points for all groups. *R*-squared estimates for Groups M2 and M3 decrease to zero at all points. Thus, at the group level, there is no evidence that the disruption and change of sensitivity, bias, and r^2 estimates in punished choice vary with the point of the menstrual cycle.

Gain-Loss Asymmetry Across Baseline and Cycle Points

Group gain-loss asymmetry ratios at each cycle point are shown in the far-right column of Table 8 and pictured in Figure 15. Values and ranges of asymmetry ratios across baseline and cycle points show little variation in Group M1, moderate variation in Group M2, and high variability in Group M3: Group M1 asymmetry range = 5.21 to .585, mean = 5.45, SEM = .13; Group M2 asymmetry range = 5.53 to 8.47, mean = 7.41, SEM = .67; Group M3 asymmetry range = 9.63 to 18.81, mean = 14.10, SEM = 2.21.

Figure 15 shows gain-loss asymmetry ratios (derived from aggregated reinforcement and response ratios) at each cycle point for each group. A visual analysis of asymmetry values at baseline and three menstrual cycle points shows that women in choice with money (Group M1) produced the lowest gain-loss asymmetry ratios at baseline compared to the other groups, and women in choice with food produced the highest ratios at baseline. No groups share similar patterns of variability in gain-loss asymmetry between cycle points, relative to baseline. This indicates that, measured in the aggregate, gain-loss asymmetry does not vary with menstrual cycle point. Compared to women in choice with money (Group M1), women in choice with food (Group M3) have gain-loss asymmetry ratios 1.8, 2.9, 2.1, and 3.5 times higher at baseline, menses-onset, peri-ovulatory, and mid-luteal points, respectively.

In summary, at the group-level of analysis using aggregated response ratios of individuals at baseline and three menstrual cycle points, there was no variation in sensitivity or r^2 estimates in gains-only or gains+punishment conditions with point of the menstrual cycle. Bias estimates for Group M3, but not Groups M1 and M2, varied across cycle points relative to baseline in gains-only conditions, and varied across cycle points relative to baseline in gains+punishment conditions in Groups M2 and M3 but not M1. Thus, regularly cycling women in complex, uncertain and risky choice with money (Group M1) demonstrated loss averse behavior (operationalized as gain-loss asymmetry ratios) but the degree of loss aversion did not vary across the menstrual cycle. Non-cycling men in the same conditions (Group M2) experienced higher baseline values of asymmetry and more variability in the degree of loss aversion across points in time that corresponded to Group M1 participants' menstrual cycle points. Regularly cycling women (Group M3) in complex, uncertain and risky choice with food have higher baseline values of asymmetry and more variability across cycle points than either of the other groups. The individual-level analysis presented in the next section explores whether participants experience variability in their response to loss as a function of the menstrual cycle.

Table 8

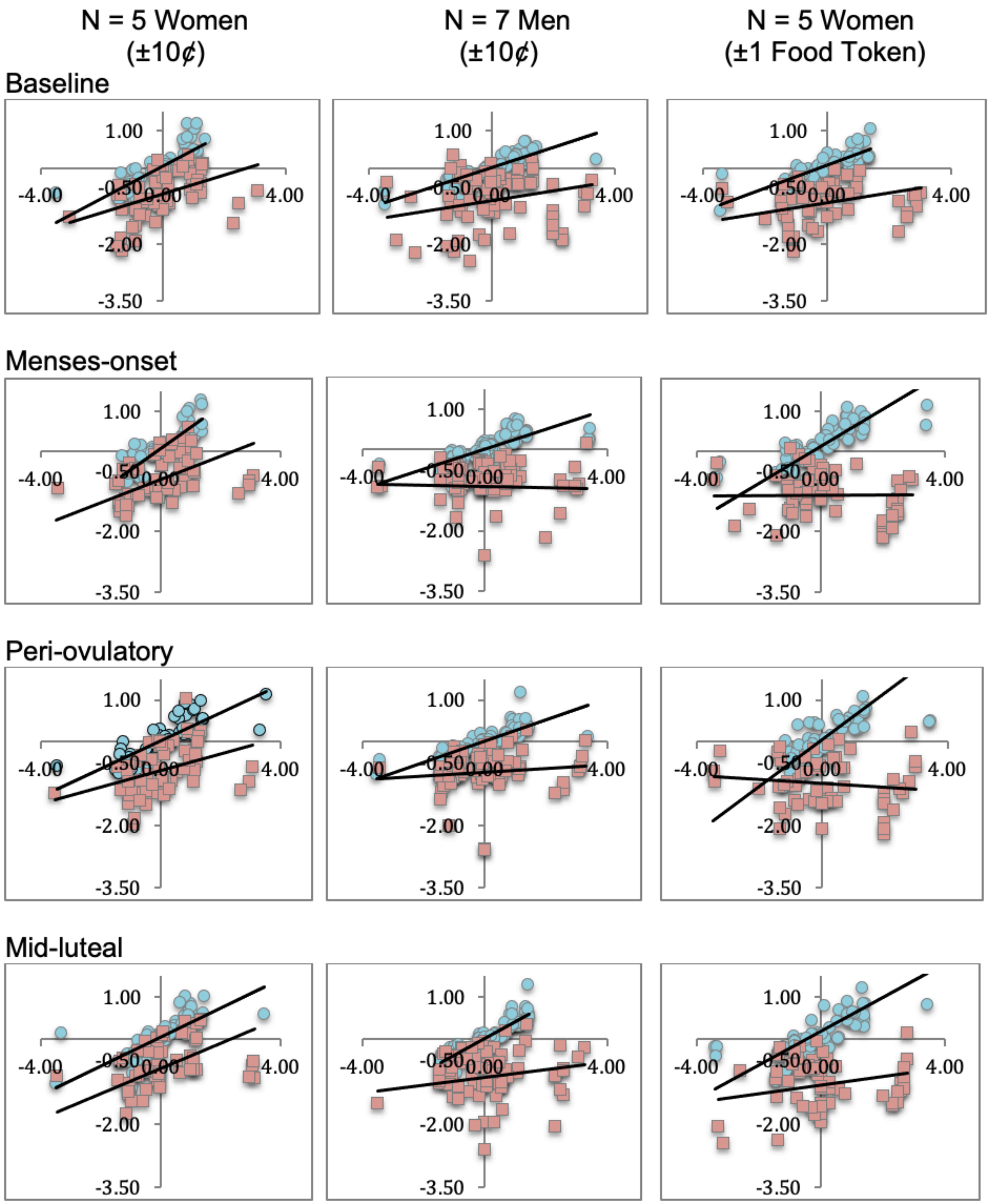
Regression Models for Groups M1, M2, and M3

Point of Menstrual Cycle	Gains-only Conditions (A_1, A_2, A_3)			Gains+punishment Conditions (B_1, B_2, B_3)			Gain-loss Asymmetry Ratio
	s	log *b*	r^2	*s*	log *b*	r^2	
Group M1 N = 5 Women (+10¢)							
Baseline	.424	.051	.66	.248	-.677	.21	5.35
Menses-onset	.530	.063	.74	.289	-.702	.22	5.82
Peri-ovulatory	.335	.024	.65	.199	-.693	.15	5.21
Mid-luteal	.339	.050	.58	.296	-.682	.24	5.40
Mean (SEM)	.407(.05)	.047(.01)	.66(.03)	.258(.02)	-.689(.01)	.21(.02)	5.45(.13)
Group M2 N = 7 Men (+10¢)							
Baseline	.264	.010	.72	.126	-.857	.04	7.36
Menses-onset	.247	.006	.60	-.014	-.912	.00	8.27
Peri-ovulatory	.254	.011	.66	.046	-.731	.01	5.53
Mid-luteal	.398	.025	.83	.092	-.903	.02	8.47
Mean (SEM)	.291(.04)	.013(.00)	.70(.05)	.063(.03)	-.851(.04)	.02(.01)	7.41(.67)
Group M3 N = 5 Women (+1 Food Token)							
Baseline	.305	.075	.67	.130	-.908	.08	9.63
Menses-onset	.461	**.125**	.52	.003	-1.102	.00	16.87
Peri-ovulatory	.558	.051	.56	-.048	-.995	.02	11.10
Mid-luteal	.401	**.190**	.49	.104	-1.085	.05	18.81
Mean (SEM)	.431(.05)	.110 (.03)	.56(.04)	.047(.04)	-1.02(.05)	.04(.02)	14.10(2.2)

Note. There is a left-choice bias in gains-only conditions at menses-onset and mid-luteal points in Group M3, but there is a sharp preference reversal to the right-choice alternative at the same points in gains+punishment conditions.

Figure 14

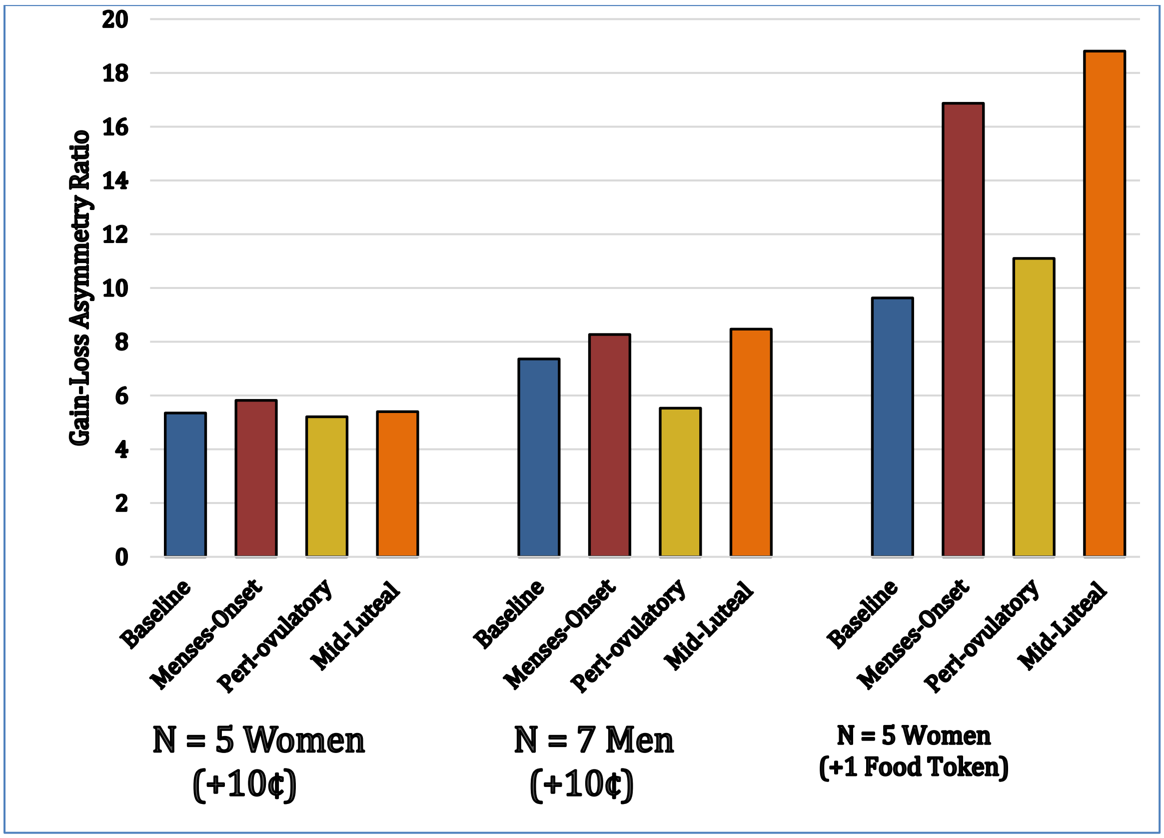
Log Response Ratios as a Function of Log Reinforcement Ratios in Gains-Only and Gains+Punishment Conditions



Note. Groups are shown in columns and point of the menstrual cycle in row (reinforcer/punisher type is indicated in parentheses). Red circles and blue squares represent a single participant's log response ratio as function of log reinforcement ratio in gains-only and gains+punishment conditions, respectively.

Figure 15

Group Gain-Loss Asymmetry Ratios at Baseline and Three Menstrual Cycle Points



Individual-Level Analysis: Gain-Loss Asymmetry and Menstrual Cycle Correlates

Tables 9, 10, and 11 show slope/sensitivity (*s*), intercept/bias (log *b*), and r^2 estimates in gains-only and gains+punishment conditions at baseline, and menses-onset, peri-ovulatory and mid-luteal points of the menstrual cycle for each participant in Groups M1, M2, and M3, respectively. Gain-loss asymmetry ratios at baseline and each cycle point for each participant are shown in the far-right column.

Group M1 N = 5 Women; Reinforcer/Punisher (±10c)

Gains-Only Conditions. All five participants have low variance in sensitivity (*s*) to reinforcers across baseline and cycle points. Three of five participants demonstrate bias estimates (log *b*) around zero at all cycle points. Participants TH-1 at menses onset and RD-1 at all points but mid-luteal, have a bias for left choice alternative, but maintain low variance across cycle points relative to baseline. R-squared values are relatively consistent across cycle points for each participant, except TH-1, and the explanatory power of reinforcement ratios for response ratios is high (r^2 greater than .70) across all cycle points for all participants but TH-1 (see Table 9).

Gains+Punishment Conditions. Sensitivity (*s*) to reinforcement is disrupted in gains+punishment conditions at all cycle points for three of five participants. Participant TH-1 has increased sensitivity to reinforcers at all cycle points and participant FF-1 has increased sensitivity at baseline and peri-ovulatory. (Interestingly, these 2 participants also experience none to relatively little loss aversion across cycle points.) All participants have low variance in sensitivity across cycle points except AJ-1. An analysis of the percent decrease of sensitivity in punished conditions showed that no two participants shared the same pattern of change in sensitivity across cycle points. An interesting note—participants in Group M1 have higher *s* values in gains-only conditions and have less disruption to *s* in gains+punishment conditions than the other groups.

All participants produced negative intercepts (log *b*) in punished conditions at all points of the cycle, indicating a strong bias for the right-side unpunished choice alternative. Participants who had a bias toward the left choice in gains-only conditions also demonstrated a strong bias for the right, unpunished choice. The degree of change in bias estimates from gains-only conditions is reflected in the gain-loss asymmetry ratio and for three participants, the bias estimate does vary across three cycle points relative to baseline. The exceptions are TH-1 and FF-1 (see Table 9).

R-squared estimates are diminished in gains+punishment conditions across all cycle points for all participants except TH-1 who produces increased r^2 estimates at all points but menses-onset. Three of five participants show moderate variance in r^2 estimates across cycle points. Interestingly, there is less disruption to r^2 estimates in gains+punishment conditions than the other groups.

Gain-Loss Asymmetry Ratios. Three of five women in Group M1 have high variance in asymmetry ratios across baseline and cycle points (see Table 9). However, a visual inspection of individuals' gain-loss asymmetry ratios across baseline and cycle points shows that no two participants share a similar pattern of fluctuation in loss averse response allocation (see Figure 16). Figure 16 shows gain-loss asymmetry ratios (y-axis) at baseline and three menstrual cycle points for each participant in each group. Individual asymmetry ratios for Group M1 N = 5 women, reinforcer/punisher (±10¢); Group M2 N = 7 men, reinforce/punisher (±10¢;) and Group M3 N = 5 women, reinforcer/punisher (±1 Food Token), are shown in the first, second, and third panel, respectively.

Summary. There is no evidence that the degree of loss averse behavior (operationalized as gain-loss asymmetry ratios) that women experience in complex, uncertain and risky choice with money, co-varies with the menstrual cycle. There was no detectable variation with cycle point and sensitivity to reinforcers in gains-only choice and no detectable variation with cycle point in decreased sensitivity and r^2 values in punished choice. No similar patterns of change in bias in punished choice across cycle points between individuals were detected and no similar patterns of change in gain-loss asymmetry ratios across cycle points between individuals were detected.

Table 9

Group M1 Participant Regression Model Parameters and Gain-Loss Asymmetry Ratios at Baseline and Three Cycle Points

Participant	Gains-only Conditions (A_1, A_2, A_3)			Gains+punishment Conditions (B_1, B_2, B_3)			**Gain-loss Asymmetry Ratio**
Cycle Point	*s*	log *b*	r^2	*s*	log *b*	r^2	
CC-1							
Baseline	.408	-.026	.93	.253	-.802	.76	**5.97**
Menses-onset	.450	.004	.90	.266	-.937	.75	**8.73**
Peri-ovulatory	.399	-.075	.92	.361	-1.047	.57	**9.39**
Mid-luteal	.474	.054	.96	.099	-.978	.17	**10.77**
Mean	.433	-.011	.93	.245	-.941	.56	8.72
(SEM)	(.02)	(.03)	(.01)	(.05)	(.05)	(.14)	(1.02)
TH-1							
Baseline	.176	.003	.71	**.258**	-.181	**.74**	**1.53**
Menses-onset	.203	**.190**	.70	**.217**	-.179	.62	**2.34**
Peri-ovulatory	.094	.067	.53	**.321**	-.264	**.69**	**2.14**
Mid-luteal	.073	.054	.12	**.310**	-.126	**.60**	**1.51**
Mean	.137	.079	.52	.277	-.188	.66	1.88
(SEM)	(.03)	(.04)	(.14)	(.02)	(.03)	(.03)	(.21)
AJ-1							
Baseline	.751	-.076	.91	.124	-1.065	.08	**9.74**
Menses-onset	.784	-.053	.91	.458	-1.388	.49	**21.67**
Peri-ovulatory	.702	.036	.92	.095	-.885	.19	**8.33**
Mid-luteal	.332	-.082	.68	.507	-1.180	.52	**12.52**
Mean	.642	-.044	.86	.296	-1.130	.32	13.07
(SEM)	(.10)	(.03)	(.06)	(.11)	(.11)	(.11)	(3.00)
RD-1							
Baseline	.737	**.221**	.85	.380	-1.054	.65	**18.81**
Menses-onset	.797	**.120**	.92	.152	-1.033	.27	**14.24**
Peri-ovulatory	.390	**.206**	.70	.207	-1.154	.35	**22.95**
Mid-luteal	.800	.033	.90	.155	-.973	.34	**10.14**
Mean	.681	.145	.84	.224	-1.054	.40	16.54
(SEM)	(.10)	(.04)	(.05)	(.05)	(.04)	(.08)	(2.78)
FF-1							
Baseline	.251	.071	.86	**.454**	-.307	.62	**2.39**
Menses-onset	.365	.051	.85	.315	-.027	.77	**1.20**
Peri-ovulatory	.298	-.022	.89	**.567**	-.142	.63	**1.32**
Mid-luteal	.440	.067	.92	.298	-.142	.69	**1.62**
Mean	.339	.042	.88	.409	-.155	.68	1.63
(SEM)	(.04)	(.02)	(.02)	(.06)	(.06)	(.03)	(.27)

Note. N = 5 women, reinforcer/punisher (±10¢.)

Group M2 N = 7 Men; Reinforcer/Punisher (±10¢)

Gains-Only Conditions. Five of seven participants have low variance in sensitivity (*s*) to reinforcers across baseline and cycle points (the exceptions are ZM-2 and JR-2). All seven participants produce bias estimates around zero at all cycle points. *R*-squared estimates are relatively consistent and show high explanatory power (r^2 greater than .70) of response ratios for reinforcement ratios for all participants across baseline and cycle points except ZM-2 and BT-2 at the periovulatory point (see Table 10).

Gains+Punishment Conditions. Sensitivity (*s*) to reinforcement is disrupted in gains+punishment conditions at all cycle points for all seven participants except JR-2 at baseline. All participants but JR-2 have low variance in sensitivity across cycle points. An analysis of the percent decrease of sensitivity in punished conditions showed that no two participants shared the same pattern of change in sensitivity across cycle points (see Table 10). An interesting note: participants in Group M2 have lower sensitivity values in gains-only conditions and have greater disruption to sensitivity in gains+punishment conditions than Group M2 in similar conditions.

All participants produced negative intercepts (log *b*) in punished conditions at all points of the cycle, indicating a strong bias for the right-side unpunished choice alternative. The degree of change in bias estimates from gains-only conditions is reflected in the gain-loss asymmetry ratio and for five participants, the bias estimate does vary across three cycle points relative to baseline. The exceptions are JD-2 and TK-2 (see Table 10).

R-squared estimates are severely reduced in gains+punishment conditions across all cycle points for all participants. Five participants show high variance in r^2 estimates across cycle points. Interestingly, disruption to r^2 estimates in gains+punishment conditions is much higher in Group M2 compared to Group M1 in similar conditions (see Tables 10 and Table 9).

Gain-Loss Asymmetry Ratios. All seven men in Group M2 have high variance in asymmetry ratios across baseline and cycle points (see Table 10). However, a visual inspection of individuals' gain-loss asymmetry ratios across baseline and cycle points shows that no two participants in Group M2 or Group M1 (women in similar choice conditions) share a similar pattern of fluctuation in loss averse response allocation (see Figure 16).

Summary. Non-cycling men in complex, uncertain and risky choice with money (Group M2) demonstrated more variability in gain-loss asymmetry across cycle points than women in similar conditions, suggesting that something other than menstrual cycle influences contribute to variability in gain-loss asymmetry. Besides that, participants in both groups had low variance in sensitivity to reinforcers across cycle points in unpunished choice. Both groups produced similar pattens of disruption to sensitivity in punished choice—only one participant in each group had high variance in sensitivity across the cycle and most men and women experienced a decrease in sensitivity while two women at multiple points and one man at one point experienced an increase. All participants demonstrated a negative bias in punished choice. Three women and five men experienced high variance in bias estimates in punished choice across the cycle points. All participants but one woman at one cycle point had reduced r^2 estimates in punished choice and three women and five men produced highly varied estimates across cycle points. Three women produced highly varied gains-loss asymmetry ratios across the cycle points relative to baseline and all seven men produced highly varied asymmetry ratios across cycle points. One woman (AJ-1) and one man (JR-2) share a similar pattern of variation in gain-loss asymmetry relative to baseline: menses-onset is highest and peri-ovulatory is lowest. These findings suggest that individual differences are more likely to influence response to loss of money than group membership based on gender or point of the menstrual cycle.

Table 10

Group M2 Participant Regression Model Parameters and Gain-Loss Asymmetry Ratios at Baseline and Three Cycle Points

Participant	Gains-only Conditions (A_1, A_2, A_3)			Gains+punishment Conditions (B_1, B_2, B_3)			**Gain-loss Asymmetry Ratio**
Cycle Point	*s*	log *b*	r^2	*s*	log *b*	r^2	
JD-2							
Baseline	.190	-.026	.92	-.011	-.352	.01	**2.12**
Menses-onset	.099	.020	.70	.078	-.304	.48	**2.11**
Peri-ovulatory	.248	.003	.88	.151	-.231	.50	**1.72**
Mid-luteal	.263	.054	.92	.221	-.301	.11	**2.26**
Mean	.200	.013	.86	.110	-.297	.28	2.05
(SEM)	(.04)	(.02)	(.05)	(.05)	(.02)	(.13)	(.12)
ZM-2							
Baseline	.363	.042	.84	-.078	-1.622	.05	**46.16**
Menses-onset	.488	.051	.87	-.047	-1.317	.05	**23.33**
Peri-ovulatory	.153	.001	.45	.039	-1.027	.01	**10.67**
Mid-luteal	.414	.006	.92	.006	-1.150	.00	**14.34**
Mean	.355	.025	.77	-.020	-1.279	.03	23.63
(SEM)	(.07)	(.01)	(.11)	(.03)	(.13)	(.01)	(7.97)
TK-2							
Baseline	.252	.011	.81	.233	-.945	.31	**9.05**
Menses-onset	.484	-.033	.89	.088	-.957	.31	**8.40**
Peri-ovulatory	.359	-.026	.94	.004	-.812	.00	**6.11**
Mid-luteal	.463	-.038	.96	.098	-.990	.38	**8.96**
Mean	.390	-.022	.90	.106	-.926	.25	8.13
(SEM)	(.05)	(.01)	(.03)	(.05)	(.04)	(.08)	(.69)
MT-2							
Baseline	.119	-.024	.74	-.119	-.164	.48	**1.38**
Menses-onset	.272	-.025	.89	-.089	-.740	.10	**5.19**
Peri-ovulatory	.257	-.029	.98	.009	-.743	.02	**5.18**
Mid-luteal	.265	-.034	.90	-.173	-.823	.14	**6.16**
Mean	.228	-.028	.89	-.093	-.618	.19	4.48
(SEM)	(.04)	(.00)	(.05)	(.04)	(.15)	(.10)	(1.06)
BT-2							
Baseline	.470	-.007	.93	-.066	-.826	.05	**6.59**
Menses-onset	.489	.013	.91	.032	-.613	.01	**4.23**
Peri-ovulatory	.359	.068	.68	.072	-.844	.06	**8.17**
Mid-luteal	.511	.047	.87	.014	-.619	.01	**4.63**
Mean	.457	.030	.85	.013	-.726	.03	5.91
(SEM)	(.03)	(.02)	(.06)	(.03)	(.06)	(.01)	(.91)

Table 10 (continued)

Cycle Point	*s*	log *b*	r^2	*s*	log *b*	r^2	Asymmetry Ratio
KG-2							
Baseline	.289	.039	.78	.016	-.607	.00	**4.42**
Menses-onset	.271	.044	.76	-.093	-.683	.39	**5.34**
Peri-ovulatory	.257	.045	.84	.026	-.557	.02	**4.00**
Mid-luteal	.317	.047	.94	-.119	-.833	.15	**7.59**
Mean	.284	.044	.83	-.043	-.670	.14	5.34
(SEM)	(.01)	(.00)	(.04)	(.04)	(.06)	(.09)	(.80)
JR-2							
Baseline	.314	.072	.80	**.510**	-1.349	.27	**26.39**
Menses-onset	.229	.092	.68	-1.658	-2.433	.25	**335.12**
Peri-ovulatory	.315	.006	.93	-.047	-.935	.00	**8.73**
Mid-luteal	.540	.077	.88	.221	-1.534	.04	**40.84**
Mean	.350	.062	.82	-.244	-1.563	.140	102.77
(SEM)	(.07)	(.02)	(.05)	(.49)	(.32)	(.07)	(77.73)

Note. N = 7 Men reinforcer/punisher (±10¢).

Group M3 N = 5 Women; Reinforcer/Punisher (±10c)

Gains-Only Conditions. Three of five participants have low variance in sensitivity (*s*) to reinforcers across baseline and cycle points (the exceptions are EL-3 and LB-3). Four women have a bias for the left choice alternative at some or all points: EL-3 at mid-luteal, LB-3 at baseline and all points of the cycle, SA-3 at baseline, and SS-3 at all points but peri-ovulatory. In comparison to bias estimates from other groups in this study and to estimates reported in similar research with money (Rasmussen & Newland, 2008), the number of participants with a left-choice bias in gains-only conditions is unusually high. It is unclear what caused this bias, but some possibilities are addressed in the discussion section. However, there are no similar patterns of bias for left or right choice alternatives across cycle points between participants. *R*-squared estimates are less consistent between cycle points compared to the other groups and high explanatory power (r^2 greater than .70) of response ratios for reinforcement ratios occurs less frequently across cycle points for some individuals (see Table 11).

Gains+Punishment Conditions. Sensitivity (*s*) to reinforcement is disrupted in gains+punishment conditions at all cycle points for all five participants except LB-3 at baseline. For two participants, EL-3, SS-3, the disruption in sensitivity results in negative slopes at all points of the cycle, but not baseline (see Table 11). A negative slope indicates that for every 1 unit increase in reinforcement ratio toward the left choice alternative, response ratios in that direction decrease, demonstrating the disruptive force of potential losses of food on sensitivity to reinforcers in these two women. Both women see the biggest disruption at the mid-luteal point and the lowest disruption at baseline but have dissimilar patterns at the other points. An analysis in percent decrease of sensitivity in gains punished choice revealed that no two participants share the same pattern of disruption across cycle points.

All participants (including those with a left-choice bias in gains-only conditions) produced negative intercepts (log *b*) in punished conditions at all points of the cycle, indicating a strong bias for the right-side, unpunished choice alternative. The degree of change in bias estimates from gains-only conditions is reflected in the gain-loss asymmetry ratio and for all five participants, the bias estimate varies across three cycle points relative to baseline.

R-squared estimates are severely reduced in gains+punishment conditions across all cycle points for all participants and four participants show high variance in r^2 estimates across cycle points (see Table 11).

Gain-Loss Asymmetry Ratios. All five women in Group M3 have high variance in asymmetry ratios across baseline and cycle points (see Table 11). A visual inspection of individuals' gain-loss asymmetry ratios across baseline and cycle points shows that two of five participants share a similar pattern of fluctuation in loss averse response allocation across cycle points: AR-3 and SS-3 (see Figure 9). For ease in comparing patterns of fluctuation of gain-loss asymmetry with cycle point (relative to baseline asymmetry) between individuals, Figure 17 shows gain-loss asymmetry ratios (y-axis) standardized to baseline ratios at baseline and three menstrual cycle points for each participant in each group. Standardized asymmetry ratios for Group M1 N = 5 women, reinforcer/punisher (±10¢); Group M2 N = 7 men, reinforce/punisher (±10¢; and Group M3 N = 5 women, reinforcer/punisher (±1 Food Token), are shown in the first, second, and third panel, respectively.

Summary. The results provide no strong evidence that the degree of loss averse behavior (operationalized as gain-loss asymmetry ratios) that women experience in complex, uncertain and risky choice with food, co-varies with three points of the menstrual cycle. There was no detectable variation with cycle point and sensitivity to reinforcers in gains-only choice and no detectable variation with cycle point in decreased sensitivity and r^2 values in punished choice. However, two of five participants (AR-3 and SS-3) have similar patterns of change in bias in punished choice across cycle points and similar patterns of change in gain-loss asymmetry ratios across cycle points relative to baseline: menses-onset is the highest and peri-ovulatory is the lowest. This pattern of variation in gain-loss asymmetry across baseline and cycle points is the same as that seen in participants AJ-1 and R-2.

Compared to regularly cycling women in choice with money, women in gains-only conditions with food experienced higher variability in sensitivity across cycle points; more instances of bias and higher variance across cycle points; and had more variability in r^2 estimates with participants producing lower values ($r^2 < .70$) across cycle points. In gains+punishment conditions, more women in choice with food had disruption to sensitivity and experienced higher rates of disruption (two women produced negative slopes at all cycle points) than women in choice with food. More women in choice with food experienced high variance in bias in gains+punishment conditions, and greater reductions and higher variance in r^2. These findings suggests that potential loss of food may have a more disruptive effect on response behavior than potential loss of money. More research in which the two choice domains are directly compared is needed to detect a differential effect of loss of food versus money.

When patterns of fluctuation in standardized gain-loss asymmetry ratios across cycle points relative to baseline are compared across participants in all three groups (see Figure 17), four of seventeen participants produce the same pattern: AJ-1, JR-2, AR-3, and SS-3 all have the highest gain-loss asymmetry at menses-onset and the lowest at peri-ovulatory, relative to baseline. These four participants produce the only pattern that occurs more than once in the 17 participants. A computerized simulation was conducted to determine the likelihood of three occurrences of the same pattern in 10 participants (regularly cycling women) and four occurrences of the same pattern in 17 participants (regularly cycling women and non-cycling men). With four states (baseline, menses-onset, peri-ovulatory, and mid-luteal), there are 24 possible patterns of change in gain-loss asymmetry relative to baseline. Given ten random draws with replacement over one million trials, the probability that three or more would result in the same pattern is 0.16. Thus, there is a 0.84 probability that the shared pattern between the three women is not due to chance and, given the timing of the measurements, the menstrual cycle is a possible factor. However, when the same experiment is repeated with 17 random draws, the probability that four or more would share the same pattern is 0.11, a 0.89 probability that the shared pattern between the three women and one man is not due to chance. This is further evidence that the shared pattern is not due to chance, but it also decreases the likelihood that the contributing factor is the menstrual cycle. While it is possible that for some women (30% in this study), gain-loss asymmetry, independent of choice domain, varies with the points of the menstrual cycle, the inclusion of the non-cycling male control group suggests that an unidentified, common factor is more likely than points of the menstrual cycle to influence fluctuation of gain-loss asymmetry.

Table 11

Group M3 Participant Regression Model Parameters and Gain-Loss Asymmetry Ratios at Baseline and Three Cycle Points

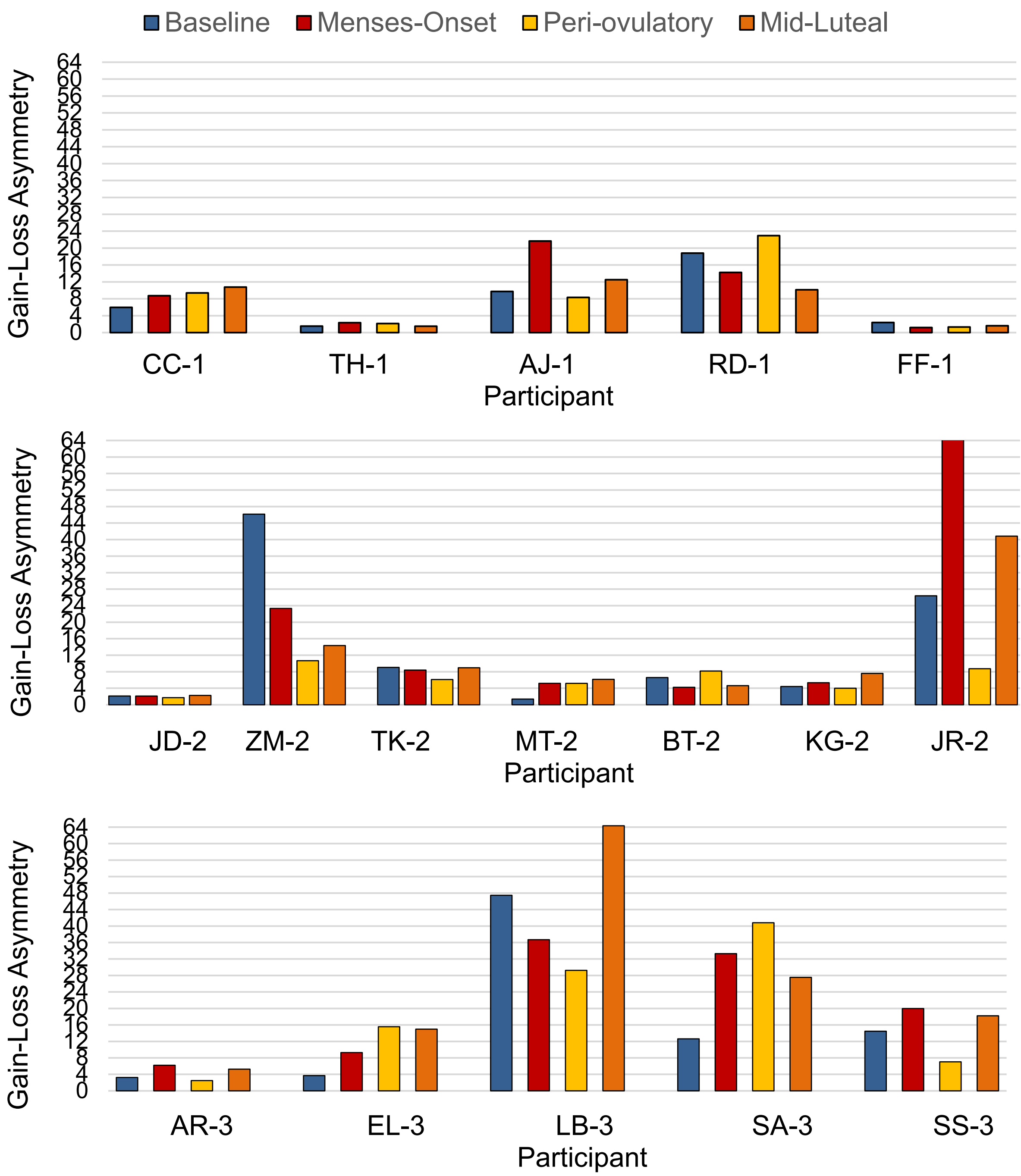
Participant	Gains-only Conditions (A_1, A_2, A_3)			Gains+punishment Conditions (B_1, B_2, B_3)			**Gain-loss Asymmetry Ratio**
Cycle Point	*s*	log *b*	r^2	*s*	log *b*	r^2	
AR-3							
Baseline	.235	-.003	.74	-.008	-.515	.01	**3.25**
Menses-onset	.257	.052	.74	.007	-.741	.00	**6.21**
Peri-ovulatory	.188	-.033	.77	.119	-.429	.38	**2.49**
Mid-luteal	.139	.074	**.58**	.082	-.648	.13	**5.27**
Mean	.205	.023	.71	.050	-.583	.13	4.31
(SEM)	(.03)	(.02)	(.04)	(.03)	(.07)	(.09)	(.86)
EL-3							
Baseline	.325	-.042	.78	.090	-.610	.11	**3.70**
Menses-onset	1.100	-.034	.84	**-.100**	-1.002	.16	**9.29**
Peri-ovulatory	1.008	.039	.83	**-.113**	-1.153	.21	**15.51**
Mid-luteal	.884	**.245**	.73	**-.148**	-.931	.12	**14.98**
Mean	.829	.052	.80	-.068	-.924	.15	10.87
(SEM)	(.17)	(.07)	(.03)	(.05)	(.11)	(.02)	(2.77)
LB-3							
Baseline	.355	**.137**	.77	**.440**	-1.540	.46	**47.46**
Menses-onset	.281	**.422**	.81	.212	-1.105	.14	**33.69**
Peri-ovulatory	.697	**.485**	**.69**	-.026	-.981	.01	**29.25**
Mid-luteal	.279	**.205**	**.63**	.276	-.604	.21	**64.34**
Mean	.403	.312	.73	.226	-1.058	.21	43.69
(SEM)	(.10)	(.08)	(.04)	(.10)	(.19)	(.09)	(7.90)
SA-3							
Baseline	.460	**.150**	.90	.025	-.952	.01	**12.62**
Menses-onset	.529	.019	.91	.055	-1.503	.05	**33.30**
Peri-ovulatory	.495	.085	.92	-.067	-1.526	.05	**40.80**
Mid-luteal	.671	.051	.96	.244	-.389	.54	**27.55**
Mean	.539	.076	.92	.064	-1.093	.16	28.57
(SEM)	(.05)	(.03)	(.01)	(.07)	(.27)	(.13)	(5.97)
SS-3							
Baseline	.138	**.155**	**.58**	-.041	-1.005	.04	**14.48**
Menses-onset	.302	**.150**	.84	**-.305**	-1.151	.38	**19.97**
Peri-ovulatory	.188	-.033	.77	**-.162**	-.842	.15	**7.05**
Mid-luteal	.188	**.200**	**.68**	**-.295**	-.060	.20	**18.22**
Mean	.204	.118	.72	-.201	-.765	.20	14.93
(SEM)	(.03)	(.05)	(.06)	(.06)	(.24)	(.07)	(2.87)

Note. N = 5 women reinforcer/punisher (±1 Food Token.)

Note. Three participants demonstrate a bias for the left choice alternative in gains-only conditions. Explanatory power of reinforcement ratios is less than .70 at some points for three participants. One participant experiences an increase in (s) in punished choice and two participants produce negative slopes at all cycle points.

Figure 16

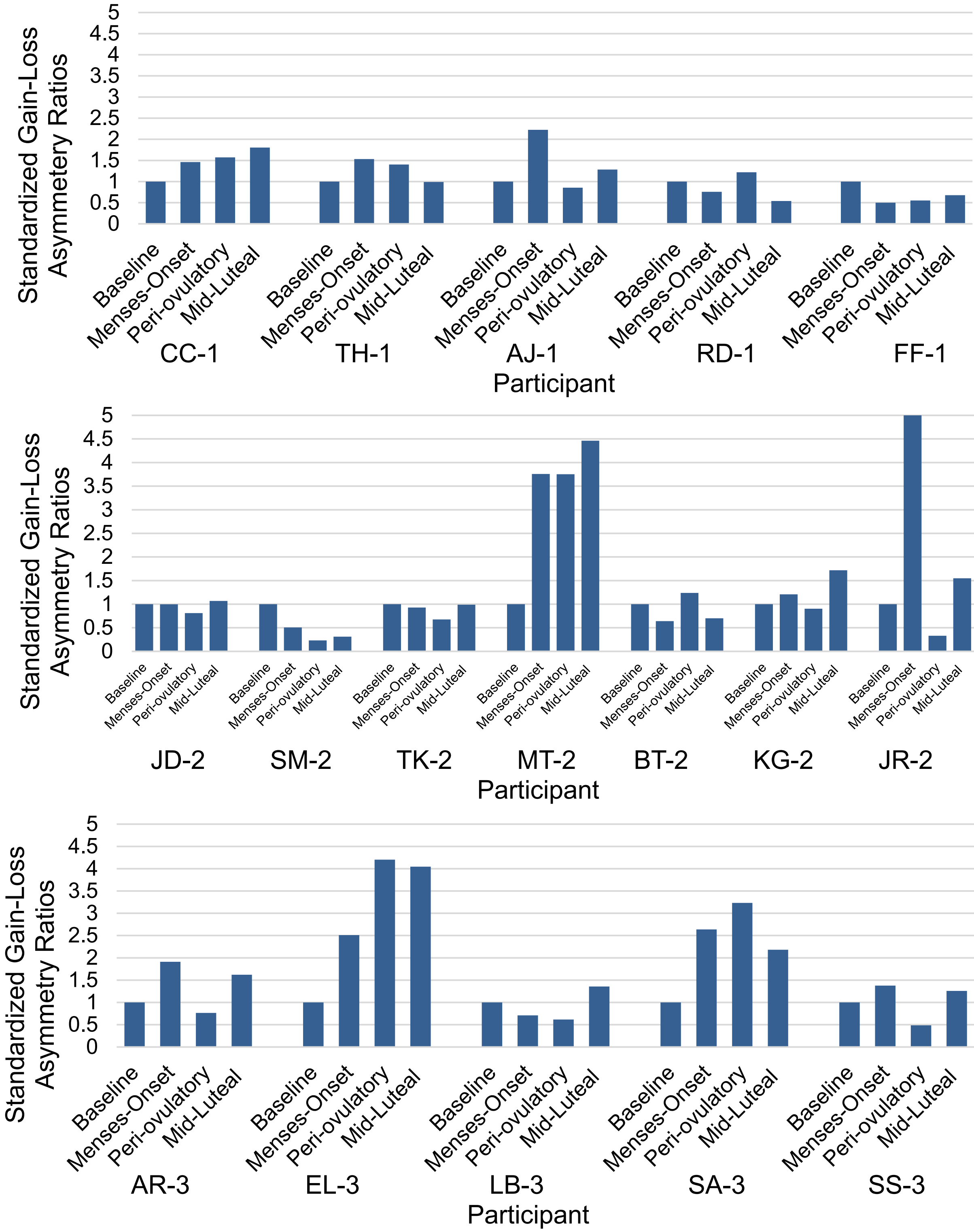
Individual Gain-Loss Asymmetry Ratios at Baseline and 3 Menstrual Cycle Points



Note. Asymmetry ratios for Group M1 N = 5 women, reinforcer (10¢); Group M2 N = 7 men, reinforcer (10¢), and Group M3 N = 5 women, reinforcer (+1 Food Token), are shown in the first, second, and third panel, respectively.

Figure 17

Standardized Individual Gain-Loss Asymmetry Ratios at Three Points of Menstrual Cycle



Note. Gain-loss asymmetry ratios are standardized to baseline and are shown for Groups M1, M2, and M3 on the top, middle and bottom panels, respectively.

Chapter 7: Discussion

General Findings

Loss aversion, operationalized as gain-loss asymmetry ratios, was replicated in both women and men in complex, recurring, uncertain, and risky choice with potential gains and losses of real money and with tokens exchanged for real food. Although individual differences in response to loss were striking, the asymmetrically larger behavioral effects of loss, relative to gains, were nearly ubiquitous. No evidence was found for co-variation of gain-loss asymmetry ratios and point of the menstrual in choice with money or food.

This replication of loss aversion provides further support for its classification as a behavioral phenomenon, not only in verbal reports of cognitive behavioral response to hypothetical scenarios (such as affective forecasting, heuristical cognition, and strategizing), but also in overt behavioral responding in which the allocation of time and effort are affected more by potential loss of both money and food than potential gains of the same.

By demonstrating a predictable, loss-averse response pattern in complex, recurring, risky and uncertain choice architectures, in which probabilities of gain-loss distribution must be learned through experience, this replication also challenges the claims of researchers who advocate for a revision of the "belief" in loss aversion or challenge its existence altogether. The experiments and the associated results highlight more contexts in which loss aversion is elicited—recurring choice with small gains or losses of money and food, which over time cumulatively add up to larger gains or losses. Further, the phenomenon of loss aversion was shown to extend from quantitative choice domains with a generalized reinforcer (money), in which it has predominantly been studied, to that of a primary reinforcer, food.

Tangentially, the experimental analysis of behavior and small-*N* experimental design were shown to be effective in predicting, detecting, and quantifying individual, loss-averse behavior. A critical feature of replicable research is its predictive utility, and, unfortunately, the predictive utility of much psychological research conducted at the group-level of analysis is never tested at either the group or individual level of behavior. This replication acts as a positive test of prior loss aversion research at the within-subject and between-subject level of analysis while clarifying the scope of the prediction—in the context of the choice architecture of the experiments, gain-loss asymmetry is predictable, but the magnitude and variability are more extreme than that previously described in the cognitive and behavioral literature.

Extreme Gain-Loss Asymmetry

Average gain-loss asymmetry ratios were 3 to 6 times greater in choice with money and 4 to 16 times greater in choice with food than those reported in the cognitive and behavioral literature. Although gain-loss asymmetry was nearly ubiquitous among participants, the range and extreme ratios that some individuals produced are not well characterized by the average—between subject variability in response to loss was high for both women and men in choice with money and with food. Of the 27 participants tested at four sessions, only one displayed a near-symmetrical effect and 23 produced ratios greater than two, indicating that potential loss had *more* than twice the effect on behavior than potential gains for 85% of the participants. In fact, 19 participants (70%) produced ratios greater than 3, 16 participants (59%) produced ratios greater than 5, and ten participants (37%) produced ratios *greater* than 10. In other words, about 88% of participants produced ratios greater than those reported in the cognitive literature and more than 70% produced ratios larger than the average ratios reported in similar behavioral research. Of the 22 participants who also tested through 16 sessions, the results were similar but even more extreme: only one had a near-symmetrical effect and 19 (86%) produced ratios greater than two; 82% produced ratios greater than 3, 73% produced ratios greater than 5; and 41% produced ratios greater than 10, an astonishingly large behavioral effect.

Possible reasons that asymmetry ratios were larger include (a) the use of real versus hypothetical consequences of choice—money and real food; (b) participants learned the reinforcement and punishment schedules via experience with the consequences of their response allocation rather than being provided information about probabilities and employing a top-down cognitive processes of prediction; (c) behavioral measures were collected hundreds of times for each participant rather than from a few hypothetical scenarios; (d) the use of extreme ratios of reinforcement (9: 1) between choice alternatives, the backdrop against which losses occurred; and (e) sensitivity to reinforcers was disrupted to a much larger degree than that reported in a similar study (which may be a result of the extreme ratios.)

Implications

These results suggest that when the probability of obtaining gains and losses from concurrent choice alternatives must be learned via experience and consequences, the effect of the bias for avoiding loss, rather than pursuing gains, is more powerful than previously understood. Individuals will forego the pursuit of potential earnings to avoid loss to an extent that could be quite damaging, depending on the context. In choice with money, these results may help explain the difficulty individuals experience when attempting to save for or invest in long-term endeavors such as home ownership and retirement, or when attempting to make profitable investment decisions which are always associated with risk. In choice with food, these results may partially explain the difficulty and lack of success individuals experience with dieting, calorie restriction, nutrient selection, quantity regulation, and scarcity triggers associated with eating disorders.

The range of responses and especially the possibility of extreme loss aversion will be critical for architectures of choice to consider when designing economic and health policies. Potential loss in recurring choice systems must be implemented or prevented judiciously to prevent disruption of future learning and sensitivity to availability of potential gains.

The Role of Individual Differences in Response to Potential Loss

The exceptionally large range of obtained gain-loss asymmetry ratios across participants, groups, and choice domains highlights the critical role that individual differences play in predicting the effect of loss on decision-making and choice response behavior.

Although the study was not designed to quantify generalized sex or gender effects, considering the role that individual differences play, to preclude possible obfuscation of response patterns that may be related to gender or sex, and to empirically investigate the myth of irrationality associated with femaleness and the menstrual cycle, sex-disaggregated data was collected and reported. The results made clear that the magnitude of response to loss of money or food tokens was highly varied in both women and men and there were no obvious gender differences—individual women or men were not predictably more or less rational or irrational than one another. No strong patterns in individual gain-loss asymmetry were detected between groups or choice domains.

However, there were some indications that women in choice with money experienced lower levels of loss aversion and women in choice with food experienced higher levels, relative to other groups. Men's response to loss was about the same in both money and food.

Women in choice with money had lower shift in bias toward the unpunished alternative during punished choice and lower and more restricted ranges of gain-loss asymmetry ratios than all other groups. Women in choice with food had higher shift in bias towards the unpunished alternatives during punished choice and higher and wider ranges of gain-loss asymmetry than all other groups.

Specifically, women in choice with money had higher sensitivity estimates in unpunished choice, less disruption to sensitivity in punished choice, and recovered some sensitivity with repeated exposure compared to the other groups. They experienced 30% less disruption in r^2 estimates in punished choice, suggesting that reinforcers of money retained their strength in punished choice at higher rates for women than reinforcers of money did for men or reinforcers of food did for women. They experienced less shift in bias towards the unpunished alternative and lower gain-loss asymmetry ratios compared to the other groups. Three women had smaller bias estimates at 16 sessions relative to four, suggesting that the effect of loss on behavior was attenuated somewhat with repeated exposure. And, for 63% of women in choice with money, gain-loss asymmetry decreased with repeated exposure to punished choice; the same was true for only 43% of men in choice with money and 29% of women in choice with food.

Additionally, in the analysis of menstrual cycle correlates and loss aversion, men in choice with money produced higher variance in gain-loss asymmetry ratios across menstrual cycle points than women in similar conditions (men SEM = 0.67, women SEM = 0.13). Men in choice with money and women in choice with food experienced greater disruption at the three points of the menstrual cycle relative to baseline compared to women in choice with money. This is further support for investigating a possible gender difference that women in choice with money experience less loss aversion than men.

In contrast, women in choice with food had a similar pattern to men in choice with money: sensitivity estimates in punished choice were similar and disruption to sensitivity in punished choice increased with repeated exposure. These women had much larger shifts in bias toward the unpunished alternative than other groups and the bias increased with repeated exposure. They produced higher gain-loss asymmetry ratios at higher ranges and more variability than other groups. At four sessions, asymmetry ratios were seven times greater than women with money and 3.5 times great than men with money and men with food; at 16 sessions, asymmetry ratios were 3.5 times greater than women with money and 2.5 greater than men with money. There was extremely high variability between participants, but the ranges are much higher than other groups and at 16 sessions, the variance is reduced such that a group difference may be likely. Further research is needed to investigate a possible interaction of gender and choice with food.

Implications

The results suggest that individual differences are more predictive of the magnitude of response to loss than gender or sex differences. This is important because the insidious myth of irrationality associated with femaleness and the menstrual cycle is based on assumptions about women being innately less rational than men. Of course, the common usage of *irrationa*l implies unreasonableness or a failure to meet a subjective standard, but if the criteria for rationality from rational choice theory are used, the results from this study discredit the myth, especially in choice with money. The dissemination of this information and other like findings will be crucial in moving toward more equitable choice environments in personal relationships, family life, and at all levels of government and policy making.

Additional research is needed to determine if there is an interaction between gender and choice domains. The more extreme response by women to loss in choice with food may be a biological phenomenon but it may also be a learned response resulting from the pervasive diet and body image culture in which women develop and live. By age 18-25, most women have internalized a thin ideal and diet culture which require caloric and nutrient restriction that could elicit loss aversion and a cascade of conflicting psychological and biological responses. While women in choice with money had the most rational response to loss relative to the other groups, men's response to loss was about the same in the money and food choice domains. However, an interaction between gender and choice domain may have been masked in men who are more likely to be exposed to and proficient in gaming culture and practices making the accumulation of points or tokens more salient than the commodities for which they were exchanged.

Loss Aversion as a Function of Disruption to Sensitivity of Reinforcers

One theory posits that loss aversion results from the disruption in sensitivity to reinforcement caused by positive punishment. While marked disruption in sensitivity to reinforcement was observed in punished choice for most participants, for 33% of participants in choice with money and 42% in choice with food, sensitivity to reinforcers *increased* in punished choice. For those with increased sensitivity in punished choice, only the women in choice with money and one man in choice with food also produced relatively low levels of loss aversion (gain-loss asymmetry ratios less than 2) while the remaining participants still produced astonishingly high asymmetry values: men in choice with money produced ratios of 9 and 26; women in choice with food produced ratios of 47 and 60; and men in choice with food produced ratios of 6 and 30. This suggests that loss aversion cannot be explained solely by a disruption in sensitivity because frequently, those who produced the highest gain-loss asymmetry ratios also demonstrated increased sensitivity to reinforcers in punished choice. Two additional mechanisms that may partially explain loss aversion are discussed in Chapter 2: error management theory, which purports that several small losses are a byproduct of avoiding larger more costly losses to achieve satisfactory, rather than optimal, gains, and operant learning, in which losses act as punishers to decrease responding.

Implications

For a large minority of participants, it appears that some risk can improve sensitivity to reinforcement—the potential for loss makes the gain more salient and more valuable. For example, participant WD-4 is completely indifferent to reinforcement through the first 28 sessions of gains-only choice—he allocates his behavior left to right equally regardless of reinforcement, and he produces sensitivity, bias, and *r*-squared values of zero. However, at session 29, when he is exposed to punished choice, his sensitivity to reinforcement increases to 0.60 and r-squared increases to 0.52, the highest values observed in punished choice with food. (Fifty percent of women in choice with money maintain higher r-squared values in punished choice.) Of the five men in choice with food, three produced a similar pattern. This suggests that the rewards of food tokens were valued more and became more salient after participants experienced the potential for their loss. An earnings analysis would be useful in determining if individuals who have low sensitivity to reinforcement in gains-only choice can increase optimization of rewards by being exposed to some risk. This could be important in choice domains in which reinforcement is novel or hard to detect, but the optimization of which, nevertheless, is critical for well-being, such as nutritive eating or token-reward systems used in any number of educational and clinical settings, including addiction recovery.

Change in Loss Averse Responding with Repeated Exposure and Learning

A key methodological and theoretical feature of the present investigation is whether the expression of loss aversion changes with recurring exposure, experience, and learning from experiencing the consequences of choice with real commodities (as opposed to discrete choice with explained probabilities of hypotheticals or few experiences with real commodities). Of the 22 participants tested at four and 16 sessions, 19 (86%) experienced a meaningful change in the magnitude of gain-loss asymmetry. However, the direction of change was not predictable: nine participants (41%) became more loss averse with repeated exposure while the effect of loss was somewhat attenuated by 10 participants (45%) who became less loss averse. Only three participants (14%) experienced constant loss aversion. Individual differences in sensitivity to reinforcement, response to loss, and associated learning are essential for understanding how the expression of loss aversion changes in recurring choice.

Implications

A possible interaction of choice domain and recurring exposure needs to be investigated further—in choice with money, 53%, 33% and 13% of participants experienced decreased asymmetry, increased asymmetry, or constant asymmetry, respectively, but in choice with food, 29%, 57%, and 14% of participants experience decreased, increased, or constant, asymmetry, respectively. This finding suggests that potential loss of food (a primary reinforcer) may affect the expression of loss aversion differently than money (a generalized reinforcer). For most women in choice with food (men were not tested at 16 sessions in choice with food), the effect of potential loss of food increased with repeated exposure, but for women and men in choice with money, the effect of potential loss of money decreased.

The observations suggest that loss aversion is a fluid, rather than static, behavioral phenomenon and that measurements of discrete choice or that use few behavioral samples may only capture a poorly characterized and poorly defined "snapshot" version of the phenomenon.

Loss Aversion Across the Menstrual Cycle

Sensitivity, bias, and gain-loss asymmetry in individuals varied across points of the menstrual cycle in women in choice with money and food *and* men in choice with money. While variance in gain-loss asymmetry across menstrual cycle points ranged from low to high in women and the matched male control group, no patterns between individuals were detected in the variation with points the menstrual cycle. However, one pattern of variation in gain-loss asymmetry across menstrual cycle points relative to baseline was observed in three women—one in choice with money and two in choice with food. The probability of this pattern occurring due to something other than chance alone is 0.84. The timing of the measurements indicates the menstrual cycle as a likely factor. The same pattern of variation in gain-loss asymmetry across menstrual cycle points was observed in one participant from the matched, non-cycling male control group. The probability of this pattern occurring four times due to something other than chance alone is 0.89. The increase in probability suggests that a non-random factor common to both the women and men is more likely than the menstrual cycle to influence the degree of gain-loss asymmetry.

Implications

Individual differences were the most likely predictor of change in asymmetry across time, not menstrual cycle points. Most participants (53%) had very low variability in gain-loss asymmetry across cycle points, 24% had moderate variability, and 23% had high variability. This is further support that for many, loss aversion appears to be more of a fluid response pattern than static.

Although the likelihood is low that the menstrual cycle is a common factor that affected the expression of loss aversion, the possibility remains that for the three of ten women who shared a common pattern, points of the menstrual cycle may play a role. Further research is warranted.

Conclusions

Importantly, this study expands knowledge of the contexts, conditions, and boundaries in which human decision-makers produce loss-averse patterns of behavioral responding: gains-loss asymmetry manifests differently in complex, recurring, uncertain and risky behavioral choice compared to discrete choice that use cognitive measures; and gain-loss asymmetry manifests differently between individuals, both in extremity of response and learning over time, and possibly between choice domains. No strong predictive evidence of covariation of gain-loss asymmetry and point of the menstrual cycle was detected.

A possible limitation is that the choice architecture for gains and losses of money both gamified and utilized a system of points and tokens. Only some recurring choice domains in everyday life use such systems, highlighting the difficulty of generalizing findings from a laboratory. Additionally, there may be some tangential effect related to gaming culture, wherein points or tokens are more salient than the purchasing power or commodity they provide access to. This may also hide a possible choice domain interaction—it is not uncommon for men to have more gaming experience and expertise and men in choice with money responded similarly to men in choice with food while women responded differently in the two domains.

Revisiting the Research Questions and Hypotheses

Research Question 1

Is loss aversion a replicable phenomenon of decision-making and choice behavior in recurring, complex, uncertain, and risky choice with real, versus hypothetical, gains and losses of money? If gain-loss asymmetry is observable in these conditions, how do obtained ratios compare to those reported in cognitive and behavioral literature? (Garnica, 2016; Kahneman & Tversky, 1979; Rasmussen & Newland, 2008).

The hypothesis that gain-loss asymmetry would be observable in recurring, complex, uncertain, and risky choice with potential gains and losses of real money was confirmed, supporting the stated rationale: if loss aversion is a behavioral phenomenon as well as a phenomenon of conscious, cognitive, and affective forecasting and strategizing, loss aversion should be measurable as a pattern of behavior allocation (a distribution of resources such as effort, time, money, between choice alternatives).

As expected, the obtained asymmetry estimates differed meaningfully from estimates reported in the cognitive and behavioral literature. Although neither the magnitude nor direction of the difference was predicted, a discrepancy between cognitive and affective forecasting and real experience was expected. Rasmussen and Newland's reported (2008) behavioral measures produced asymmetry ratios 1.3 times greater than those in Kahneman and Tversky's (1979) original cognitive studies. The obtained ratios in the present study were more extreme than both: 3 to 6 times greater than the cognitive and 2 to 5 times greater than the behavioral research.

Precise quantitative comparisons of the behavioral effects of potential gains versus potential loss require qualitatively and quantitatively similar stimuli. Simple choice between such stimuli rarely occurs in non-laboratory decision-making and choice-tasks. Choice with money is the closest approximation (the reason most research on loss aversion has been conducted in the economic and monetary domains), but even money is often closely associated with gains and losses of all other resources, such as food, shelter, social currency, mate selection, hedonic rewards, etc. While the reinforcing effect of money is ubiquitous, individuals' symbolic representation of its utility will vary. Individual differences in practical utility may be elicited at a higher degree when real, versus hypothetical, money is on the line.

i. Do dimes (exchanged for more convenient currency) function as reinforcers?

ii. Do losses of obtained dimes act as punishers?

iii. Is there an identifiable, quantifiable, functional relationship between response allocation among alternatives and reinforcement schedules of coins?

Coins acted as strong reinforcers: response strength was highly positively correlated with reinforcement schedules. The percentage of variance in response behavior accounted for by reinforcers was high ($r^2 > 0.80$) for participants in choice with money.

Loss of coins acted as punishers demonstrated by reduced response strength in punished choice. Potential loss of money disrupted sensitivity to reinforcement for most participants, caused a shift in bias toward the unpunished alternative in all participants, and decreased the explanatory power of reinforcement for response behavior for all participants except one woman in choice with money.

Functional relationships between response strength, and reinforcement and punishment schedules of coins were established. Response strength in unpunished choice with money was stable and resistant to the effects of potential loss in punished choice.

Research Question 1a. *How do the behavioral effects of losses of money, relative to gains, change over time with repeated learning experience?*

Testing the hypothesis that gain-loss asymmetry estimates would change meaningfully with repeated exposure to unpunished and punished choice with gains and losses of money produced mixed results. Only two men of the 15 participants tested in choice with money maintained a constant level of asymmetry at 16 sessions, but of the 13 who experienced change in response to loss, a small majority experienced decreased loss aversion and just under half experienced increased loss aversion. For participants who produced extreme ratios, it is unclear how to characterize the practical implication of the change. For example, participant ZM-2 valued potential loss as 46.0 times more than an equivalent gain at four sessions and 20.0 times greater at 16 sessions. What is clear, is that at both levels the effect on behavior is astonishing. In the few participants who produced smaller ratios, the practical impact is more easily interpretable—at four sessions participant MS-1 valued loss two times more than an equivalent gain, but by 16 sessions she valued gains and losses equally.

The soundness of the rationale for excluding a prediction on the direction or magnitude of change in gain-loss asymmetry was strengthened: It is expected that, over time and with repeated exposure to unpunished choice, learning will occur. It is possible that sensitivity to reinforcement will increase, the effects of loss will be attenuated, and responding will in shift in the direction of matching. It seems equally likely that, if participants experience a relatively large asymmetrical hedonic effect of loss, they may instead increasingly avoid potential loss.

Research Question 1b. *When data is collected and reported in a sex-disaggregated fashion, are there any indications of possible sex/gender differences in gain-loss asymmetry in choice with money?*

No hypothesis was provided for this exploratory question, but due to high variability in both groups, no strong evidence was detected to indicate that women or men were more, or less, loss averse than one another.

Future Research. Several observations suggested that, as a group, more women in choice with money were more sensitive to reinforcement, that sensitivity was disrupted less in punished choice, that reinforcement explained more variance in response behavior in punished choice, and that women were less loss averse than men in similar conditions. The range of variability was more restricted, and group mean ratios were lower for women than men. The degree of loss averse behavior decreased in both groups with repeated exposure and experience in punished choice, but the effect of loss was attenuated by 63% of women compared to 43% of men. Women also experienced 30% less disruption in the explanatory power of reinforcement at both points, compared to men. Further research is needed to investigate the possibility that, in general, women have a predictably different response to loss of money.

Of all participants who had increased sensitivity in punished choice, only the women in choice with money also demonstrated low levels of loss aversion. Further research is needed to determine if there is a gender effect of higher and more resilient sensitivity to reinforcers of money in complex, uncertain and risky choice.

And finally, an earnings analysis that examines the relationship between sensitivity in unpunished choice, the level of disruption in sensitivity in punished choice, and gain-loss asymmetry would help to clarify the profiles of better versus worse optimizers and the degree to which loss aversion impacts overall gains as opposed to optimization at the level of discrete choice.

Research Question 2

Is loss aversion a generalizable and replicable principle of decision-making and choice across choice domains, e.g., in a non-quantitative choice domain of food, in recurring, complex, uncertain, and risky choice with gains and losses of real food?

The hypothesis that patterns of loss-averse responding would be apparent in recurring, complex, uncertain, and risky choice with gains and losses of real food was confirmed. Because food is a primary reinforcer necessary for survival, it is possible that decision and choice mechanisms have developed to ensure the most consistent and reliable supply possible and that avoiding losses of current food supplies may compete with the utility of pursuing further gains.

i. Do food tokens (exchanged for real food) function as reinforcers, i.e., make future responding more likely?

ii. Do losses of obtained food tokens act as punishers, i.e., make future responding less likely?

iii. Is there an identifiable, quantifiable, functional relationship between response allocation among alternatives and reinforcement schedules of food tokens?

Food tokens exchanged for real food acted as reinforcers. Response strength was positively correlated with reinforcement schedules ($r^2 > 0.61$).

Loss of food tokens acted as punishers demonstrated by reduced response strength in punished choice. Potential loss of food tokens disrupted sensitivity to reinforcement for most participants, caused a shift in bias toward the unpunished alternative in all participants, and decreased the explanatory power of reinforcement for response behavior for all participants but one man.

Functional relationships between response strength, reinforcement schedules, and punishment schedules were established. Response strength in unpunished choice was stable and resistant to the effects of potential loss in punished choice.

Research Question 2a. *How do gain-loss asymmetry estimates in choice with real food compare with those reported in choice with real money?*

The hypothesis that gain-loss asymmetry estimates would be meaningfully higher for decisions with food than in similar conditions with money, was not confirmed. There was extremely high between-subject variability in asymmetry ratios in choice with money and food making it unclear if one choice domain predictably elicited higher, or lower, gain-loss asymmetry. Choice with real food resulted in ratios that were 6 to 16 times and 4 to 12 times higher than those reported in the monetary domain of cognitive and behavioral literature, respectively. In comparison, obtained ratios in choice with money were 3 to 6 times greater those reported in the cognitive research and 2 to 5 times greater than the behavioral research. At four sessions, average asymmetry ratios in choice with money were 11.1 (SEM = 3.3) compared to 24.1 (SEM = 13.3) in choice with food. Because men were not tested at 16 sessions in choice with food, no average is available. Future research could include testing individuals in both domains and controlling for the gamification/point/token effects.

Because food is a primary reinforcer necessary for survival, it is likely that decision and choice mechanisms have developed to ensure a consistent and reliable supply and that avoiding losses of current food supplies may compete with the utility of pursuing further gains.

Research Question 2b. *How do the behavioral effects of losses of food, relative to gains, change over time with repeated learning experience?*

The hypothesis that gain-loss asymmetry estimates would change meaningfully with repeated exposure to unpunished and punished choice with gains and losses of money was only tested in women, not men, and produced mixed results. Only one of seven women tested in choice with food maintained a constant level of asymmetry at 16 sessions, but of the six who experienced change in response to loss, four experienced more extreme loss aversion. This is the opposite pattern of women in choice with money—in 63% of women in choice with money, the effect of loss was attenuated with repeated exposure to punished choice (gain-loss asymmetry ratios were lower); the same was true for only 29% of women in choice with food.

All women produced ratios larger than 3 at all sessions and generally, ratios were high to extreme. As in choice with money, it is unclear how to characterize the practical implication of the change. For example, participant RM-3 valued potential loss 160.0 times more than an equivalent gain at four sessions and 63.0 times more at 16 sessions. Two women with ratios ~3.0 at 4.0 sessions increased to 4.0 and 9.0 at 16 sessions, the only 2 women to produce smaller ratios at 16 sessions had astronomically high ratios at 4 (47.0 and 160.0), and of the remaining four, three produced larger ratios. Taken together, these observations indicate that with repeated exposure and learning, most women increased their gain-loss asymmetry and add remarkably high levels of loss aversion.

Research Question 2c. *When data is collected and reported in a sex-disaggregated fashion, are there any indications of possible sex/gender differences in gain-loss asymmetry in choice with food?*

The hypothesis that gain-loss asymmetry estimates obtained from recurring, complex, uncertain, and risky choice with gains and losses of real food will be meaningfully higher in women than those obtained from men was not confirmed to do extreme variability. However, women's response to loss of food was more extreme and more varied than all other groups. Because of high costs related to reproduction, it is plausible that females are more loss averse as a mechanism of error management that is biased towards certain types of errors to avoid more devastating errors. Avoiding potential losses from a current food supply, a primary reinforcer necessary for survival of self and offspring, rather than pursuing gains of future food supplies, may be just such a bias. Given the appearance of a possible interaction of potential food loss and gender and the importance this may have for eating disorders, dieting, obesity, and complications with body image, further research is warranted

Limitations. The use of food tokens in this study facilitated the quantification of gains and losses of food, a non-monetary stimulus, but it also added an extra level of learning and association that money did not require—participants had to learn the value of food tokens via experience in exchanging tokens for real food. This may have affected the asymmetrical effect of potential losses in some way. For example, most women in unpunished choice with food (a) increased in sensitivity at 16 sessions, relative to four, suggesting that food tokens became increasingly more salient with repeated exposure, and (b) produced higher asymmetry ratios, suggesting that as salience of tokens increased, the effect of losing them became more pronounced.

The use of food tokens also added a possible confound—the observed response may have been partially a response to the potential loss of points or tokens in general rather than to food specifically. The high between-subject variability in the money and food groups precluded a decisive answer, although, as detailed, there appeared to be a meaningful difference between women's response to food compared to the other groups. Future research would need to test women and men in all conditions (choice with tokens only, dimes only, or food only) and determine if gain-loss asymmetry varied with the commodity.

Also, four of seven women in choice with food had a bias for the left choice alternative in unpunished choice. Compared to other groups and similar behavioral studies with money, this is an unusually high proportion of participants with bias in gains-only choice. One possible explanation is that condition A_1 (reinforcement schedule 9: 1, left: right) was always presented first. The value of food tokens relative to real food had to be learned and the first, richer option of each session may have become preferred. However, given the pronounced shift toward the right, unpunished alternative in punished choice, it is unclear how much, if any, the pre-punished bias for the left side affected gain-loss asymmetry ratios in that group.

Research Questions 3 and 4

Do gain-loss asymmetry estimates observed in recurring, complex, uncertain, and risky choice with money (or food) vary with three points of the menstrual cycle (menses-onset, peri-ovulatory, and mid-luteal)?

The hypothesis that gain-loss asymmetry estimates in choice with money would not vary meaningfully with points of the menstrual cycle was confirmed. It was assumed that any biological processes selected to regulate reproduction (like the menstrual cycle) would not influence decision-making and choice with money when the choice was distinct and isolated from social meaning or mating repercussions. Although beliefs and learned behaviors surrounding the menstrual cycle likely do influence non-reproductive behaviors, the experimental design minimized social expectations and performance demands related to beliefs about the menstrual cycle.

The hypothesis that gain-loss asymmetry estimates in choice with food would vary meaningfully with points of the menstrual cycle was not confirmed. It was reasoned that the phases of the menstrual cycle, and their associated physiological effects and physical symptoms, might plausibly function as motivating operations to influence the value of available gains and losses of food. Because some research has suggested that caloric and nutritional intake and needs vary across the menstrual cycle, it is plausible that loss and risk are more salient at different points of the cycle as reproductive and nutritional needs and costs fluctuate. Because two of five women shared the same pattern of covariance in gain-loss asymmetry and points of the menstrual cycle, the menstrual cycle may influence some women's response to potential loss of food. Further research in choice with food is warranted as well as other choice domains with relevance to reproduction, such as social, mating, and sexual choice.

i. Does sensitivity to reinforcers of money (or food) in gains-only conditions vary with points of the menstrual cycle?

ii. Does the degree of disruption in sensitivity to reinforcers of money (or food) in gains+punishment conditions vary with points of the menstrual cycle?

Sensitivity to reinforcers (of money or food) in gains-only conditions did not vary with points of the menstrual cycle, nor did the degree of disruption in sensitivity to reinforcers (of money or food) in gains+punishment conditions.

The key takeaway from the menstrual analysis was its contribution to dismantling the insidious myth of irrationality associated with femaleness and the menstrual cycle. While the possibility remains that for three of ten women, the menstrual cycle may have played a role in the response to loss, the high between-subject variability and the within-group ranges of ratios shows that individual differences are more likely to predict one's response to loss than one's gender. Interestingly, in choice with money, the aggregated behavioral response showed that women’s behavior was much less variable across the cycle points than men’s.

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Appendix A

FoodSearch Order Sheet and Personal Earnings Record

FoodSearch Order Sheet & Personal Earnings Record

Participant:_______________________________
Date: ______________________
Lab#: ______________________
RA : _________________________

Session #	Gains	Losses	Net Earnings (gains – losses)
Day's Total Net Earnings:			

Item	Food Token Cost	# of Item	Total Food Token Cost
Counter			
Peanut Butter	50		
Pop Tarts	40		
Fresh Fruit–novelty	80		
Bananas	10		
Muffins/ Donuts	30		
Mints / Gum	3		
Chips / Snack bags	25		
Hot chocolate - SM	10		
Orange/Plum	3		
Popcorn - KS	10		
Oatmeal	40		
Granola Bags – large	90		
Pancakes - Kodiak	40		
Kind bar & Nut Bar - KS	25		
Fruit Snacks - BF	3		
Corn nuts	20		
Chocolates - Godiva	3		
Chocrooms	10		
Oreos	30		
Jerky - Oberto	30		
Candy bars	25		
Granola Bars - NV	10		
P3-protein packs	30		

Item	Food Token Cost	# of Item	Total Food Token Cost
Apple Sauce/Peaches	15		
Protein Bar - KS	30		
Nut packs -BD & Planter	30		
Cliff bars	25		
Gatorade	20		
Ritz Crackers	15		
Trail Mix bags -Kirkland	15		
Fridge			
Cheese slices-Tillamook	5		
Balanced Breaks-Sargen	25		
Regular yogurt-Yoplait	20		
Greek yogurt-Chobani	25		
Naked juice	30		
Apple	15		
Chocolate milk	25		
Orange juice	25		
2% milk – dairy pure	25		
String cheese	5		
Protein bar – G2G	40		
Freezer			
Egg pockets- hot pocket	30		
Single pizza	30		
Brekky bowls – JimmyDean or Açai	40		
Brekky sandwiches: JD croissant or Engl muffin	30		
Chicken bakes - KS	35		
Fudge bar – HC	20		
Ice cream-Haagen Dazs	20		
Total Food Token Cost (for all items)			
Balance (day's total net earnings – total food token cost for all items)			

Participant initials: _____________
RA initials:________________________

Appendix B

Mean Obtained Reinforcers (+10¢) and Associated Mean Responses Across Experimental Conditions for *Group 1 N = 8 Women*

This table includes mean proportion of obtained reinforcers (with mean obtained reinforcers in the left and right choice alternatives) and mean proportion of responses allocated to the left choice alternative (with mean responses allocated to both the left and right choice alternative, L: R) for each condition for each participant.

Obtained reinforcers and responses are presented for (a) the last 12 of 24 sessions (sessions 13-24) with gains-only conditions A_1, A_2, and A_3; (b) the last four of the initial eight sessions (sessions 29-32) with gains-only and gains+punishment conditions A_1, B_1, A_2, B_2, A_3, and B_3; and (c) the last 16 of 20 sessions (sessions 29-44) with gains-only and gains+punishment conditions A_1, B_1, A_2, B_2, A_3, and B_3.

All ratios and proportions are presented in terms of left: right (L: R) choice alternatives.

$A_1A_2A_3B_1B_2B_3$: Experimental Condition
$Reinforcers_{obt}$ L: Mean Obtained Reinforcer Left Proportion (with mean obtained reinforcers L: R)
Responses L: Mean Response Left Proportion (with mean responses L: R)
.90, .50, .10: Scheduled Available Reinforcers Left Proportion

Partic.	Sessions quantity (session #)	**A_1 $Reinforcers_{obt}$ L Responses L .90**	**B_1 $Reinforcers_{obt}$ L Responses L .90**	**A_2 $Reinforcers_{obt}$ L Responses L .50**	**B_2 $Reinforcers_{obt}$ L Responses L .50**	**A_3 $Reinforcers_{obt}$ L Responses L .10**	**B_3 $Reinforcers_{obt}$ L Responses L .10**
CC-1	12	.93 (25: 2)	-	.52 (11: 10)	-	.12 (3: 23)	-
	(13-24)	.75 (403: 137)	-	.50 (283: 280)	-	.28 (162: 416)	-
	4	.93 (26: 2)	.89 (17: 2)	.53 (10: 9)	.45 (9: 11)	.08 (2: 22)	.15 (4: 22)
	(29-32)	.71 (383:155)	.24 (107:338)	.51 (287: 275)	.13 (63: 441)	.26 (146: 415)	.10 (51: 472)
	16	.91 (29: 3)	.88(15: 2)	.48 (10: 11)	.50 (9: 9)	.08 (2: 23)	.12 (3: 23)
	(29-44	.76 (426: 135)	.19 (84: 358)	.49 (284: 292)	.11 (54: 452)	.25 (143: 432)	.07 (38: 519)
TH-1	12	.91 (21: 2)	-	.56 (9: 7)	-	.09 (2: 20)	-
	(13-24)	.70 (367:159)	-	.52 (296: 274)	-	.36 (200: 355)	-
	4	.87 (20:3)	.86 (19: 3)	.47 (9: 10)	.52 (9: 9)	.09 (2: 21)	.07 (2: 26)
	(29-32)	.61 (321:207)	.55(208:174))	.47 (258: 294)	.40 (193: 288)	.41 (220: 320)	.23 (120:398)
	16	.86 (18: 3)	.89 (17: 2)	.44 (7: 9)	.53 (8: 7)	.20 (4: 16)	.09 (2: 20)
	(29-44	.64 (348:197)	.55 (222:180)	.52 (299: 274)	.40 (198: 294)	.47 (253: 288)	.27 (142: 386)
AJ-1	12	.92 (23: 2)	-	.50 (10: 10)	-	.12 (3: 23)	-
	(13-24)	.88 (1205: 168)	-	.50 (722: 717)	-	.16 (221:1180)	-
	4	.88 (23: 3)	.88 (7:1)	.67 (14: 7)	.36 (4:7)	.12 (3: 22)	.06 (1: 16)
	(29-32)	.86 (1021:166)	.24 (247: 810)	.52 (631: 581)	.23 (143:1053)	.13 (155:1003)	.06 (71: 1173)
	16	.92 (22: 2)	.91(10: 1)	.56 (10: 8)	.42 (5: 7)	.12 (3: 22)	.05 (1: 21)
	(29-44	.83 (986: 208)	.23 (248: 868)	.51 (627: 600)	.13 (145: 1036)	.16 (181: 981)	.06 (72:1098)
RD-1	12	.92 (22: 2)	-	.47 (8: 9)	-	.08 (2: 23)	-
	(13-24)	.88 (894: 124)	-	.44 (447: 573)	-	.17 (177: 840)	-
	4	.88 (21: 3)	.93 (14: 1)	.47 (8: 9)	.45 (5: 6)	.07 (2: 25)	.08 (2: 23)
	(29-32)	.90 (998: 115)	.30 (306: 712)	.44(447: 573)	.11 (119: 927)	.21 (234: 861)	.02 (21: 1065)

	16 (29-44)	.88 (21: 3) .89(1017:124)	.92 (12: 1) .22 (227:819)	.50 (9: 9) .52 (614: 562)	.50 (6: 6) .10 (111: 975)	.12 (3: 22) .22 (248: 894)	.09 (2: 21) .04 (45: 1075)
FF-1	12 (13-24)	.87 (20: 3) .68 (567: 266)	- -	.50 (10:10) .51 (452: 436)	- -	.09 (2: 21) .37 (338: 553)	- -
	4 (29-32)	.86 (18: 3) .70 (521: 227)	.89 (17: 2) .53 (296: 270)	.50 (10: 10) .50 (366: 363)	.44 (8: 10) .45 (300: 372)	.07 (2: 25) .32 (229: 484)	.12 (3: 21) .13 (92: 645)
	16 (29-44	.88 (21: 3) .70 (433: 182)	.90 (18: 2) .62 (281: 183)	.53 (10: 9) .52 (355: 324)	.46 (9:10) .48 (278: 309)	.12 (3: 22) .33 (217: 444)	.11 (3: 21) .17 (109: 547)
GD-1	12 (13-24)	.91 (20: 2) .64 (467: 258)	- -	.53 (9:8) .52 (437: 397)	- -	.09 (2: 21) .37 (316: 533)	- -
	4 (29-32)	.92 (24: 2) .83 (504: 107)	.87 (13: 2) .29 (182: 452)	.45 (8: 10) .42 (307: 425)	.41 (7: 10) .24 (155: 502)	.16 (4: 21) .23 (159: 540)	.12 (3: 22) .16 (109: 569)
	16 (29-44	.92 (23: 2) .78 (561: 159)	.88 (7:1) .13 (100:641)	.50 (10: 10) .48 (378:408)	.45 (5: 8) .13 (103: 668)	.13 (3: 21) .29 (225: 551)	.12 (3: 22) .13 (100: 685)
MS-1	12 (13-24)	.90 (24: 3) .60 (891: 595)	- -	.48 12: 13) .50 (798: 802)	- -	.08 (2: 24) .41 (644: 922)	- -
	4 (29-32)	.89 (24: 3) .61 (874: 557)	.88 (7: 1) .31(195:442)	.52 (13: 12) .51 (798: 782)	.50 (9: 9) .38 (455: 733)	.14 (4: 24) .40 (610: 905)	.11 (3: 24) .32 (470:1009)
	16 (29-44	.88 (23: 3) .60 (896: 603)	.83 (5: 1) .36 (136:239)	.52 (113: 12) .49 (780: 798)	.57 (8: 6) .39 (362: 565)	.12 (3: 23) .40 (612: 904)	.12 (3: 23) .39 (584: 904)
EZ-1	12 (13-24)	.90 (18: 2) .61 (384: 244)	- -	.50 (7: 7) .51 (432: 419)	- -	.10 (2: 19) .40 (363: 548)	- -
	4 (29-32)	.91 (21: 2) .83 (578: 116)	.91 (3: .3) .06 (42: 610)	.47 (7: 8) .56 (554: 438)	.25 (1: 3) .10 (72: 638)	.11 (2: 16) .31 (339: 747)	.10 (1: 10) .11 (100: 834)
	16 (29-44)	.91 (20: 2) .80 (471: 116)	.91 (10: 1) .26 (125:352)	.50 (6: 6) .57 (448: 336)	.43 (3: 4) .30 (177: 423)	.11 (2: 17) .31 (265: 590)	.13 (2: 14) .21 (171: 656)

Appendix C

Mean Obtained Reinforcers (+10¢) and Associated Mean Responses Across Experimental Conditions for Group 2 N = 7 men.

This table includes mean proportion of obtained reinforcers (with mean obtained reinforcers in the left and right choice alternatives) and mean proportion of responses allocated to the left choice alternative (with mean responses allocated to both the left and right choice alternative, L: R) for each condition for each participant.

Obtained reinforcers and responses are presented for (a) the last 12 of 24 sessions (sessions 13-24) with gains-only conditions A_1, A_2, and A_3; (b) the last four of the initial eight sessions (sessions 29-32) with gains-only and gains+punishment conditions A_1, B_1, A_2, B_2, A_3, and B_3; and (c) the last 16 of 20 sessions (sessions 29-44) with gains-only and gains+punishment conditions A_1, B_1, A_2, B_2, A_3, and B_3. All ratios and proportions are presented in terms of left: right (L: R) choice alternatives.

$A_1A_2A_3B_1B_2B_3$: Experimental Condition
$Reinforcers_{obt}$ L: Mean Obtained Reinforcer Left Proportion (with mean obtained reinforcers L: R)
Responses L: Mean Response Left Proportion (with mean responses L: R)
.90, .50, .10: Scheduled Available Reinforcers Left Proportion

Partic.	Session quantity (session #)	A_1 $Reinforcers_{obt}$ L Responses L .90	B_1 $Reinforcers_{obt}$ L Responses L .90	A_2 $Reinforcers_{obt}$ L Responses L .50	B_2 $Reinforcers_{obt}$ L Responses L .50	A_3 $Reinforcers_{obt}$ L Responses L .10	B_3 $Reinforcers_{obt}$ L Responses L .10
JD-2	12	.90 (22: 2)	-	.47 (12: 14)	-	.11 (3: 24)	-
	(13-24)	.50 (583: 582)	-	.48 (597: 638)	-	.47 (567: 643)	-
	4	.88 (23: 3)	.93 (19: 2)	.44 (11: 14)	.54 (12: 11)	.08 (2: 25)	.16 (4: 22)
	(29-32)	.57 (678: 510)	.31 (309: 694)	.49 (603: 620)	.31 (381: 846)	.35 (522: 990)	.31 (440: 1004)
	16	.92 (24: 2)	.89 (19: 2)	.49 (12: 12)	.48 (11: 11)	.09 (2: 23)	.11 (3: 24)
	(29-44)	.63 (868: 502)	.42 (466: 695)	.53 (759: 690)	.34 (463: 885)	.38 (567: 916)	.29 (429: 1022)
ZM-2	12	.90 (21: 2)	-	.53 (8: 7)	-	.11 (2: 20)	-
	(13-24)	.77 (455: 138)	-	.53 (357: 321)	-	.22 (146: 526)	-
	4	.80 (17: 4)	.95 (3: 0)	.49 (8: 8)	.39 (4: 7)	.09 (2: 21)	.09 (1: 15)
	(29-32)	.72 (497: 194)	.02 (13: 797)	.47 (345: 387)	.05 (34: 686)	.22 (168: 582)	.05 (32: 718)
	16	.85 (18: 3)	.84 (3: 1)	.54 (8: 7)	.58 (4: 5)	.08 (2: 21	.08 (2: 20)
	(29-44	.72 (525: 219)	.09 (71: 718)	.50 (405: 397)	.12 (98: 662)	.26 (219: 595)	.08 (60: 699)
TK-2	12	.90 (20: 2)	-	.51 (10: 9)	-	.08 (2: 23)	-
	(13-24)	.71 (1027: 427)	-	.50 (744: 734)	-	.29 419: 1011)	-
	4	.87 20: 3)	.86 (6:1)	.46 (10: 11)	.51 (5: 5)	.07 (2: 26)	.06 (1: 16)
	(29-32)	.66 (1001: 512)	.21 (130: 762)	.50 (768: 772)	.17 (130: 762)	.25 (368: 1099)	.08 (49: 1046)
	16	.89 (22: 3)	.90 (7: 1)	.46 (9: 11)	.50 (7: 7)	.10 (3: 23)	.09 (2: 21)
	(29-44	.70 (994: 436)	.16 (162: 1046)	.48 (702: 751)	.14 (162: 1046)	.26 (376: 1050)	.09 (109: 1190)
MT-2	12	.87 (19: 3)	-	.53 (9: 9)	-	.11 (2: 20)	-
	(13-24)	.58 (560: 399)	-	.49 (513: 523)	-	.39 (379: 601)	-
	4	.93 (24: 2)	.86 (16: 3)	.47 (11: 12)	.62 (12: 7)	.08 (2: 23)	.07 (2: 20)
	(29-32)	.61 (616: 396)	.31 (296: 662)	.51 (553: 530)	.36 (363: 637)	.37 (392: 659)	.53 (562: 496)

	16 (29-44	.90 (22: 2) .63 (630: 373)	.88 (12: 2) .19 (191: 811)	.47 (10: 11) .47 (499: 559)	.50 (8: 9) .19 (187: 822)	.09 (2: 22) .35 (364: 670)	.08 (2: 23) .30 (309: 691)
BT-2	12 (13-24)	.88 (22: 3) .63 (978: 570)	- -	.47 (11: 12) .48 (790: 866)	- -	.11 (3: 22) .39 (638: 1013)	- -
	4 (29-32)	.87 (22: 3) .73 (1259: 460)	.94 (10: 1) .17 (240: 1016	.52 (12: 11) .54 (947: 816)	.46 (7: 10) .19 (296: 1232)	.10 (3: 26) .23 (397: 1300)	.08 (2: 24) .11 (183: 1496)
	16 (29-44	.89 (23: 3) .77 (1292: 394)	.93 (10: 1) .18 (226: 870)	.52 (12: 11) .52 (905: 836)	.53 (10: 9) .27 (414: 1114)	.09 (2: 26) .23 (379: 1283)	.09 (3: 25) .12 (195: 1445)
KG-2	12 (13-24)	.91 (22: 2) .67 (912: 454)	- -	.46 (10: 12) .50 (674: 668)	- -	.09 (2: 23) .37 (487: 839)	- -
	4 (29-32)	.88 (23: 3) .70 (954: 405)	.90 (11: 1) .29 (341: 866	.61 (12: 8) .49 (638: 660)	.46 (7: 8) .19 (220: 967)	.11 (3: 22) .40 (504: 762)	.12 (3: 21) .21 (267: 1039)
	16 (29-44	.90 (23: 2) .70 (939: 394)	.85 (10: 2) .19 (220: 974)	.55 (11: 9) .50 (643: 646)	.51 (7: 7) .18 (209: 983)	.11 (3: 22) .39 (486: 761)	.11 (3: 22) .20 (258: 1010)
JR-2	12 (13-24)	.91 (22: 2) .70 (353: 153)	- -	.47 (9: 10) .49 (261: 272)	- -	.12 (3: 21) .38 (213: 342)	- -
	4 (29-32)	.90 (21: 2) .74 345: 123)	.99 (10: 0) .18 (81: 393)	.58 (12: 8) .50 (245: 244)	.42 (5: 7 .35 (166: 323)	.10 (2: 21) .38 (190: 306)	.10 (2: 10) .18 (90: 430)
	16 (29-44	.91 (21: 1) .75 (349: 117)	.99 (4: 0) .09 (40: 431)	.54 (9: 8) .50 (244: 247)	.50 (7: 7) .25 (119: 366)	.14 (3: 19) .36 (179: 318)	.11 (2: 18) .24 (118: 379)

Appendix D

Mean Obtained Reinforcers (+1 Food Token) and Associated Mean Responses Across Experimental Conditions for Group 3 N = 7 Women.

This table includes mean proportion of obtained reinforcers (with mean obtained reinforcers in the left and right choice alternatives) and mean proportion of responses allocated to the left choice alternative (with mean responses allocated to both the left and right choice alternative, L: R) for each condition for each participant.

Obtained reinforcers and responses are presented for (a) the last 12 of 24 sessions (sessions 13-24) with gains-only conditions A_1, A_2, and A_3; (b) the last four of the initial eight sessions (sessions 29-32) with gains-only and gains+punishment conditions A_1, B_1, A_2, B_2, A_3, and B_3; and (c) the last 16 of 20 sessions (sessions 29-44) with gains-only and gains+punishment conditions A_1, B_1, A_2, B_2, A_3, and B_3.

All ratios and proportions are presented in terms of left: right (L: R) choice alternatives.

$A_1A_2A_3B_1B_2B_3$: Experimental Condition
Reinforcers_{obt} L: Mean Obtained Reinforcer Left Proportion (with mean obtained reinforcers L: R)
Responses L: Mean Response Left Proportion (with mean responses L: R)
.90, .50, .10: Scheduled Available Reinforcers Left Proportion

Partic.	Sessions quantity (session #)	**A_1** **Reinforcers_{obt} L** **Responses L** **.90**	**B_1** **Reinforcers_{obt} L** **Responses L** **.90**	**A_2** **Reinforcers_{obt} L** **Responses L** **.50**	**B_2** **Reinforcers_{obt} L** **Responses L** **.50**	**A_3** **Reinforcers_{obt} L** **Responses L** **.10**	**B_3** **Reinforcers_{obt} L** **Responses L** **.10**
AR-3	12 (13-24)	.91 (21: 2) .64 (672: 384)	- -	.46 (9: 11) .50 (550: 557)	- -	.09 (2: 22) .36 (373: 663)	- -
	4 (29-32)	.89 (22: 3) .60 (379: 252)	.92 (8: 1) .23 (186: 635)	.59 (14: 9) .57 (465: 354)	.51 (7: 8) .25 (213: 630)	.15 (4: 21) .37 (345: 595)	.05 (1: 23) .23 (194: 639)
	16 (29-44	.93 (23: 2) .69 (500: 218)	.87 (6: 1) .27 (194: 600)	.46 (10: 11) .51 (453: 433)	.50 (7: 7) .24 (190: 640)	.12 (3: 22) .37 (331: 570)	.09 (2: 22) .18 (153: 703)
EL-3	12 (13-24)	.91 (18: 2) .61 (199:132)	- -	.51 (6: 7) .52 (228: 210)	- -	.12 (2: 17 .38 143: 230)	- -
	4 (29-32)	.90 (17: 2) .62 (186: 199)	.89 (10: 1) .26 (86: 247)	.30 (3: 7) .48 (187: 212	.50 (5: 5 .23 (74: 282	.08 (1: 15) .25 (97: 277)	.10 (2: 16) .18 (68: 310)
	16 (29-44	.92 (17: 1) .79 (258: 67)	.94 (5: 1 .11 (38: 339)	.46 (4: 5) .54 (202: 184	.50 (4: 4) .15 (50: 321)	.08 (1: 15) .28 (107: 268	.10 (2: 17) .15 (57: 315)
LB-3	12 (13-24)	.91 (18: 1) .80 (359: 94)	- -	.53 (6: 5) .60 (298: 205)	- -	.12 (2: 15) .33 (167: 325)	- -
	4 (29-32)	.87 (14: 2 .71 (315: 131)	.95 (5: 1) .17 (76: 401)	.55 (7: 6) .60 (301: 200)	.27 (2: 5) .09 (43: 446)	.07 (2: 20) .37 (173: 297)	.05 (1: 165 .01 (5: 466)
	16 (29-44	.90 (16: 2) .79 (321: 87)	.89 (5: 1) .21 (57: 402)	.48 (5: 6) .64 (286: 164)	.46 (2: 5) .09 (43: 446)	.09 (1: 16) .37 (173: 297)	.06 (1: 15) .10 (40: 375)
SA-3	12 (13-24)	.89 (18: 2) .59 (221: 154)	- -	.50 (7: 7) .51 (239: 233)	- -	.08 (2: 21) .34 (147: 272)	- -
	4 (29-32)	.91 (21: 2) .85 (435: 77)	.91 (7: 1) .15 (72: 431)	.39 (7: 12) .47 (248: 281)	.43 (4: 6) .12 (64: 452)	.10 (2: 22) .24 (126: 385)	.06 (1: 21) .14 (74: 457)

	16 (29-44	.91 (18: 1) .82 (385: 85)	.89 (4: 1) .09 (40: 436)	.48 (9: 10) .49 (241: 248)	.53 (3: 4) .07 (35: 450)	.09 (2: 22) .24 (120: 362)	.08 (1: 19) .06 (29: 463)
SS-3	12 (13-24)	.93 (18: 1) .50 (166: 167)	- -	.48 (7: 8) .50 (194: 197)	- -	.12 (2: 17) .50 (190: 188)	- -
	4 (29-32)	.89 (19: 2) .68 (242: 113)	.54 (2: 1) .05 (194: 197)	.50 (10: 10) .60 (240: 172)	.41 (2: 3) .12 (55: 387)	.11 (3: 21) .44 (165: 218)	.07 (1: 17) .16 (63: 359)
	16 (29-44)	.92 (22: 2) .75 (273: 90)	.50 (10: 10) .05 (23: 436)	.50 (10: 10) .55 (228: 200)	.38 (2: 3) .15 (66: 384	.10 (2: 20) .44 (183: 228)	.09 (2: 20) .25 (106: 310)
AF-3	12 (13-24)	.86 (16: 2) .56 (190: 47)	- -	.56 (8: 7) .48 (199: 220)	- -	.11 (2: 19) .40 (210: 1)	- -
	4 (29-32)	.82 (12: 2) .41 (148: 223)	.82 (5: 1) .09 (36: 365)	.38 (5: 8) .22 (89: 309)	.34 (3: 6) .08 (29: 369)	.14 (2: 12) .26 (104: 295	.14 (2: 11) .07 (29: 369)
	16 (29-44	.88 (12: 1) .60 (168: 120)	.88 (3: .01) .06 (21: 313)	.50 (4: 4) .39 (125: 204)	.44 (2: 3) .08 (26: 301)	.16 (2: 11) .31 (97: 223)	.10 (1: 13) .06 (20: 298)
RM-3	12 (13-24)	.89 (20: 2) .58 (183: 130)	- -	.47 (8: 9) .50 (188: 192)	- -	.09 (2: 20) .45 (153: 184)	- -
	4 (29-32)	.95 (23: 1) .68 (193: 95)	.**50 (3: .01)** .03 (13: 396)	.63 (12: 7) .65 (237: 130)	.50 (1: 2) .02 (7: 401	.16 (3: 16) .55 (194: 163)	.10 (1: 12) .01 (5: 365)
	16 (29-44	.89 (20: 2) .61 (196: 126)	.73 (2: .01) .03 (14: 423)	.55 (9: 7) .59 (228: 160)	.46 (1: 2 .03 (11: 411)	.13 (2: 17 .48 (177: 196)	.09 (1:16) .10 (35: 330)

Appendix E

Mean Obtained Reinforcers (+1 Food Token) and Associated Mean Responses Across Experimental Conditions for Group 4 N = 5 Men

This table includes mean proportion of obtained reinforcers (with mean obtained reinforcers in the left and right choice alternatives) and mean proportion of responses allocated to the left choice alternative (with mean responses allocated to both the left and right choice alternative, L: R) for each condition for each participant.

Obtained reinforcers and responses are presented for (a) the last 12 of 24 sessions (sessions 13-24) with gains-only conditions A_1, A_2, and A_3; (b) the last four of the initial eight sessions (sessions 29-32) with gains-only and gains+punishment conditions A_1, B_1, A_2, B_2, A_3, and B_3; and (c) the last 16 of 20 sessions (sessions 29-44) with gains-only and gains+punishment conditions A_1, B_1, A_2, B_2, A_3, and B_3.

All ratios and proportions are presented in terms of left: right (L: R) choice alternatives.

$A_1A_2A_3B_1B_2B_3$: Experimental Condition
$Reinforcers_{obt}$ L: Mean Obtained Reinforcer Left Proportion (with mean obtained reinforcers L: R)
Responses L: Mean Response Left Proportion (with mean responses L: R)
.90, .50, .10: Scheduled Available Reinforcers Left Proportion

Partic.	Sessions quantity (session #)	A_1 $Reinforcers_{obt}$ L Responses L .90	B_1 $Reinforcers_{obt}$ L Responses L .90	A_2 $Reinforcers_{obt}$ L Responses L .50	B_2 $Reinforcers_{obt}$ L Responses L .50	A_3 $Reinforcers_{obt}$ L Responses L .10	B_3 $Reinforcers_{obt}$ L Responses L .10
AD-4	12	.90 (23: 2)	-	.46 (9: 11)	-	.09 (2: 22)	-
	(13-24)	.78 (284: 80)	-	.48 (192: 206)	-	.33 (128: 256	-
	4	.92 (25: 2)	.83 (13: .01)	.42 (9: 13)	.44 (3: 1)	.14 (4: 23)	.07 (1: 19)
	(29-32)	.85 (266: 45)	.57 (149: 157	.50 (171: 176)	.11 (46: 343	.29 (104: 243	.06 (28: 325)
NS-4	12	.86 (19: 3)	-	.46 (10: 11)	-	.11 (3: 23)	-
	(13-24)	.60 (542: 365)	-	.48 (457: 501)	-	.34 (303: 598)	-
	4	.93 (25: 2)	.79 (1: .01)	.58 (15: 11)	.33 (1: 2)	.12 (3: 24)	.07 (2: 23)
	(29-32)	.63 (664: 399)	.02 (18: 989)	.51 (573: 559)	.03 (32: 1013)	.41 (453: 658)	.25 (281: 875)
NP-4	12	.89 (16: 2)	-	.50 (6: 6)	-	.09 (2: 18)	-
	(13-24)	.53 (275: 248)	-	.53 (335: 286)	-	.34 (182: 342)	-
	4	.91 (16: 2)	.90 (13: 1)	.46 (8: 9)	.31 (4: 11)	.03 (1: 16)	.07 (1: 14)
	(29-32)	.48 (205: 226)	.36 174: 338)	.50 (258: 261)	.38 (192: 329)	.22 (125: 448)	.12 (69: 534)
SL-4	12	.93 (25: 2)	-	.50 (9: 9)	-	.10 (2: 22)	-
	(13-24)	.84 (245: 46)	-	.50 (180: 180)	-	.19 (65: 274)	-
	4	.91 (23: 2)	.90 (16: 2)	.44 (8: 10)	.54 (9: 7)	.15 (3: 18)	.10 (2: 22)
	(29-32)	.84 (269: 52)	.49 (133: 153)	.39 (145: 224)	.46 (164: 176)	.21 (79: 290)	.13 (46: 297)
WD-4	12	.92 (17: 2)	-	.48 (7: 8)	-	.12 (2: 15)	-
	(13-24)	.46 (249: 295)	-	.45 (262: 321)	-	.48 (276: 297)	-
	4	.87 (13: 2)	.90 (10: 1)	.47 (5: 6)	.38 (4: 7)	.07 (2: 20)	.04 (1: 16)
	(29-32)	.48 (254: 270)	.20 (92: 378)	.49 (308: 334)	.22 (112: 414)	.39 (196: 305)	.11 (51: 409)