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EXPERIMENTAL ANALYSIS OF GAMBLING USING A CONCURRENT-SCHEDULES PROCEDURE

Andrew Ellis Brandt, Ph.D.

Western Michigan University, 2010

Gambling has been experimentally investigated using various types of gambling simulations designed to mimic the contingencies found in real-world games of chance. Findings from past risky choice research suggest that certain procedures used in existing gambling simulations may systematically increase levels of gambling. Two of these characteristics, the use of a participant stake and the type of options available during gambling, were tested in four experiments in which participants had the opportunity to gamble using tokens exchangeable for entries into a $50 lottery. Experiments 1 and 2 tested persistence on a gamble option when either a single-option or a concurrent gamble no-gamble option was available. In Experiment 1, during concurrent conditions choice of the gamble option probabilistically produced tokens and choice of the no-gamble option progressed the game to the next trial. Gambling levels were similarly high in both the gamble and no-gamble options. In Experiment 2, the no-gamble option also produced tokens, i.e., token production, and gambling greatly decreased when token production was concurrently available with gambling. In Experiment 3, a concurrent gamble token-production procedure was used to test preference for a gamble option when participants were or were not staked with tokens prior to a
session. Under no-stake conditions, participants could only gamble with tokens earned by choosing the no-gamble option. Choices of the gambling option per choice opportunity were higher under stake than no-stake conditions, but only on the first exposure to the task. Experiment 4 investigated the effects of the value of the token-production option on gambling levels and showed that gambling levels were low regardless of condition. Together, the findings from these experiments suggested that existing gambling procedures that have only a single-gamble option or on which an initial participant stake is given might generate higher levels of gambling compared to when a concurrent token-production option is also available or when participants are not given an initial stake. These findings suggest that common features of laboratory-gambling tasks may elevate risk taking and that a concurrent gamble token-production procedure may therefore be a more useful procedure for investigating gambling.
ACKNOWLEDGEMENTS

At each stage of this dissertation project, I have been fortunate to have had the support of a great academic advisor, Dr. Cynthia Pietras. Over the last several years, her extensive research experience and endless encouragement have helped me to develop both the background knowledge and technical expertise needed to carefully design, execute, and disseminate these experiments. Moreover, she has provided an exemplar of mentorship that I hope to emulate as I continue my teaching and research work with my own students.

I also have considerable gratitude for the members of my dissertation committee, Dr. Wayne Fuqua, Dr. Scot Gaynor, and Dr. Dorothea Lerman. They have given me their complete support during this project and their feedback during my dissertation proposal and defense was much appreciated. Finally, I would like to thank Dr. Jeffrey Weatherly for shaping my early interests in the field of behavior analysis and gambling behavior and for continuing to support my research activities.

Andrew Ellis Brandt
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INTRODUCTION

Humans often choose among options that produce unpredictable outcomes and a considerable amount of psychological and economic research has therefore been directed towards understanding decision making in situations involving uncertainty and risk. Historically, human decision-making has been studied in the laboratory using tasks that arrange risky choices. Risky-choice tasks that involve gambling have been a favored method for studying risky choice primarily because unpredictable monetary outcomes can be easily arranged in laboratory settings, and because gambling is viewed as a valid model of choice under uncertainty (see Kahneman & Tyversky, 1984). More recently, however, gambling has begun to receive considerable attention among researchers and clinicians as a behavior of interest in its own right. This growing interest in gambling may be attributed in part to the increasing availability of legalized gambling worldwide and to the fact that a majority of adults (86%) report to they have gambled in their lifetime (see National Gambling Impact Study Commission [NGISC] final report, 1999).

The increased interest in gambling research may also be attributed to the negative impact that gambling can have on human health and welfare. One peculiar characteristic of gambling is that gambling often persists despite producing a net loss of reinforcement (i.e., in most cases, the reinforcer is money; see Skinner, 1953). Thus, excessive gambling has the propensity to produce financial hardship for a gambler, especially when wagering exceeds a person’s assets (i.e., wagering borrowed money). In addition, a small proportion (1-3%) of people who gamble develop a compulsive pattern of responding called pathological gambling (see APA DSM-IV, 1994; Beaudoin & Cox,
1999; Loba, Stewart, Klein, & Blackburn, 2001; Volberg, 1994). This disorder is characterized by gambling beyond one’s means, committing illegal acts in order to continue gambling, and viewing gambling as a legitimate way to recoup previous losses. In general, these individuals tend to experience occupational, family, or health-related problems, in addition to monetary losses due to their gambling behavior (Petry & Armentano, 1999).

Although the etiology of pathological gambling remains unclear, most evidence has suggested a strong relationship between the availability of legalized gambling and both the amount of gambling and the prevalence of pathological gambling symptoms in the surrounding population (Abbott & Volberg, 2000; Room, Turner, & Lalomiteanu, 1999; Sévigny, Ladouceur, Jacques, & Cantinotti, 2008). Not unlike other countries, the United States (U.S.) has recently experienced a rapid growth in gambling availability (see below), which suggests a growing need for research directed at understanding the factors that generate and maintain gambling in both pathological and non-pathological populations (see Petry & Armentano, 1999). One problem has been that most research on risky choice that has purportedly studied gambling behavior has not been designed to inform the analysis of gambling *per se*. That is, although choice under uncertainty has generated considerable research, risky-choice studies described as investigations of gambling are typically designed to analyze variables that influence decision making under uncertainty more broadly. For instance, Kahneman and Tversky (1984) noted:

Risky choices, such as whether or not to take an umbrella and whether or not to go to war, are made without advance knowledge of their consequences. Because
the consequences of such actions depend on uncertain events such as the weather or the opponent’s resolve, the choice of an act may be construed as the acceptance of a gamble that can yield various outcomes with different probabilities. (p. 341)

Because the majority of risky-choice research has not been designed to address gambling specifically, most laboratory risky-choice procedures fail to replicate the contingencies arranged in natural gambling environments (e.g., those found in casinos). As a result, the extent to which the findings from this research generalize to an analysis of gambling on games of chance remains unclear.

Recently, operant psychologists have made clear advances in the degree to which laboratory procedures mimic naturalistic gambling contingencies by developing simulated games of chance based on games typically found in the natural environment (see MacLin & Dixon, 2004). These procedures offer many advantages over typical risky decision-making procedures, which often use verbally-presented gambles with hypothetical outcomes and measure choice during brief assessments (often on a single trial). Conversely, simulated-gambling procedures typically give participants repeated opportunities to gamble on one or more gamble options, thereby allowing performance to be influenced by the experienced contingencies rather than by the verbal descriptions of the gamble. Simulated-gambling procedures therefore expose participants to gambling contingencies that more closely mimic those found in natural gambling environments, and as a result, performance on these procedures are likely to have greater ecological validity than performance obtained from other methods.
Although simulated-gambling procedures have many advantages over typical risky-choice procedures, the contingencies they arrange still differ from those found in gambling contexts outside the laboratory (see below). It is uncertain whether those differences significantly affect the likelihood of gambling, thus, the primary goals of the present research were to: (a) evaluate the effects on gambling of several common features of simulated-gambling procedures and (b) develop and test a new procedure that was designed to better model real-world gambling contingencies. In the following sections, common methods of studying gambling are critically reviewed and a new simulated-gambling procedure is described. First, however, a brief historical overview of gambling and gambling-related problems are discussed in order to highlight the growing need to study gambling.

**Historical Overview**

Gambling has played a role in human cultures throughout the world for several millennia (see France, 1902). Interestingly, evidence from the historical record shows that the negative consequences of gambling, especially the financial and personal hardships that sometimes result from excessive gambling, have been well known since ancient times (see Aristophanes, 423 B.C.E.; Juvenal, circa 100; Steinmetz, 1870). Despite these problems, gambling has remained a viable business opportunity and source of entertainment in many parts of the world throughout much of recorded history. Of course, its availability has also been met with considerable opposition as well, for instance, legalized gambling in the United States (U.S.) has experienced several eras of legalization and prohibition since the early American colonies.
The most recent era of legalization in the U.S. started in the early 1930’s as an effort to boost state revenue following the economic crisis that followed the 1929 stock-market crash (Thompson, 1997). A much larger wave of legalized gaming followed the recommendations made by the 1976 Commission on the Review of the National Policy Toward Gambling (CRNPTG; 1976). This commission, established by the U.S. federal government, suggested that legalized-gaming legislation should be a state rather than a federal government responsibility. As a result, all but two states (Utah and Hawaii) now allow some type of gaming, including casinos, pari-mutuel wagering, charitable gaming, and lotteries.

The expansion of both private-equity and state-sponsored gaming in the U.S. occurred despite warnings from the 1976 CRNPTG about the negative social and economic impacts of widespread gaming. For example, members of the commission cited evidence of the problematic relationship that existed between gaming availability and the prevalence of gambling-related problems, including pathological gambling. Although relatively little data were available on pathological gambling when the commission issued its report, their warnings were confirmed by subsequent research. For instance, a significant correlation between gaming availability and the prevalence of pathological gambling in a given area is now well-established (Abbott & Volberg, 2000; Room et al., 1999). Furthermore, the prevalence of pathological gambling appears to be increasing across many demographic groups, and the rates of bankruptcy and unemployment are significantly higher among pathological gamblers than non-gamblers (NGISC, 1999).
These trends are especially troubling given that the availability of legalized gaming continues to increase. Following the expansion of legalized gaming in the U.S., the total revenue of the gaming industry (based on earnings from all gaming sources) has grown at a compound annual rate of over 9%, from $10.4 billion in 1982 to over $90.9 billion in 2006 (American Gaming Association, 2008; NGISC, 1999). Interestingly, an increase in gaming availability is also occurring worldwide, for example, according to the New York Times (Barboza, 2007) and Reuters (Leung, 2009), as of 2006 China's gaming center in Macao had greater gaming revenues than Las Vegas and recently experienced annual revenue growth that exceeded 20%. The professional-services firm PricewaterhouseCoopers estimated in 2009 that gaming revenues worldwide would continue to steadily grow to an estimated annual revenue of $155 billion by 2012 (revenues were $114 billion in 2007).

Several factors are likely to contribute to the continued expansion of legalized gaming in the U.S. and other countries. First, as indicated by survey data collected by the NGISC (1999), a large proportion of the population enjoys gambling and therefore its continued availability is likely to receive strong social support in many areas. Second, the gaming industry has produced economic benefits that are unparalleled by most other industries, including employment opportunities, business taxes, payroll taxes, and other taxes paid directly to state and local governments (see the American Gaming Association, 2008, for an industry sponsored review). If the availability of gaming continues to increase, however, there will likely be a corresponding increase in gambling-related problems, including pathological gambling. These, as well as other
consequences of increased gaming availability have been extremely difficult to quantify economically, thus, the true economic benefits of legalized gambling remains unclear.

Nevertheless, there is a growing need to investigate the variables that influence gambling. Moreover, it is important that studies of gambling produce findings that extend outside the laboratory into the natural gambling environment. One way to improve the generality of gambling research is to develop laboratory-gambling procedures that closely model those environments.

METHODS FOR STUDYING UNCERTAINTY: HUMAN DECISION-MAKING RESEARCH

Definitions of Gambling and Risky Choice

Before discussing methods that have been used for studying gambling, it will be useful to define several terms commonly used in the analysis of gambling and risky-decision making. The behavior of “gambling” may be defined as a decision to make a wager, i.e., an investment of a reinforcer (usually money), in exchange for the opportunity to probabilistically gain a reinforcer of greater value (see McGlothlin, 1956). Although a gamble involves choice under uncertainty, it may be distinguished from other types of risk taking by the fact that a gamble requires an initial wager (i.e., response cost) and therefore it always has the potential to produce a loss for the gambler. Although other types of risks may also involve negative outcomes, the initial wager of a commodity is unique to a gamble. Hereafter, an option that produces uncertain outcomes is described as a gamble if it requires a wager and as a risk if it does not.
The distinction between a gamble and a risk is important because gambles and risks differ in how the contingencies are quantified. Because a gamble requires an initial wager and a risk does not, the net value of a win (i.e., a reinforcer) produced by a gamble must always incorporate the wager value. For example, if a gamble requires a $3 wager to play and produces a win of $10, then the gambler experiences a net gain of $7, whereas if a risk produces a win of $10, then the gambler experiences a net gain of $10.

The outcome value of a risk is typically quantified using mathematical expected value (EV) (see Edwards, 1955):

$$EV = \sum (p \times A)$$

where, for all possible outcomes, $p$ is the probability of a particular outcome with a net value $A$. A simple example of a risk is illustrated by a game in which rolling a “6” on one roll of a six-sided die produces $12 and all other outcomes produce $0. This risk has an expected value of $2:

$$EV = \left[\left(\frac{1}{6}\right) \times 12\right] + \left[\left(\frac{5}{6}\right) \times 0\right] = 2$$

Across many plays of the risk, then, an average gain of $2 per risk would be expected.

The $EV$ for a gamble can also be calculated. For example, if the previous risk required a $1 wager in order to play, the expected value of the gamble would be $1.

$$EV = \left[\left(\frac{1}{6}\right) \times 11\right] + \left[\left(\frac{5}{6}\right) \times -1\right] = 1$$

Of course, the $EV$ of any risk or gamble may be very different from the obtained value (the net loss or gain of reinforcers that results from playing the risk of gamble), however, the expected value and obtained values tend to converge as the number of plays increases.
Because a gamble always involves an initial wager (investment) by the gambler, its value can also be expressed as a return on investment. The mean amount returned by a gamble, or rate of return, is calculated as the proportion of the wager. This quantity has also been called the gamble’s percentage payback (PP) and is calculated as:

\[ PP = \sum \left( \frac{p \cdot A_R}{A_W} \right) \times 100\% \]

where \( A_W \) is the wager value and \( A_R \) is the value returned (i.e., \( A + A_W \)). From the previous $1 gamble, the PP is 200%:

\[ PP = \left( \frac{1/6 \cdot 12}{1} + \frac{5/6 \cdot 0}{1} \right) \times 100\% = 200\% \]

Notice that gambles with a negative EV will always have a PP less than 100%, and gambles with a positive EV will always have a PP greater than 100%. Casino games, for instance, always have a PP less than 100%.

Unlike EV, PP expresses gains as a proportion of the amount wagered. This characteristic is illustrated in the previous gamble which was expected to produce a $1 net gain, or a 200% return on investment, for each $1 wager (i.e., the gambler would expect to get $2 back for every $1 wagered on average). Nevertheless, these two calculations express the same information for a gamble and either value can be converted to the other using the following calculations:

\[ PP = \left( \frac{EV + A_W}{A_W} \right) \times 100\% \]

\[ EV = \left( \frac{PP \cdot A_W}{100\%} \right) - A_W \]
It is impossible to convert between $EV$ and $PP$ for a risk because $PP$ is undefined when the wager is zero.

**General Methods**

As noted above, decision-making research has used gambling as a model for understanding human decision-making under conditions of uncertainty. Although the procedures used in these studies have varied greatly, they typically involved *single-decision procedures* in which a choice among a pair of options was presented once to participants in a discrete-trial format (e.g., Preston & Baratta, 1948; Thaler & Johnson, 1990; Tversky, 1967). Thus, in single-decision procedures, participants are often given only a single opportunity to make their choice for a particular risk or gamble, and a different risk or gamble is presented on each subsequent trial. The risk or gamble is described verbally to the participant and included information about the wager value, probability of winning or losing, and the outcome values. Participants generally indicate their choice verbally to the experimenter.

Although some decision-making studies using single-decision procedures have used real monetary outcomes, most have used hypothetical outcomes (for a review, see Weber, Shafir, & Blais, 2004). For example, in a study by Kahneman and Tversky (1979), after a participant indicated his or her choice among the risky options no game was played and no outcomes were actually delivered. Rather, the experimenter simply presented the next option. Part of the rationale for using hypothetical outcomes was that it allowed experimenters to assess risky choice for monetary amounts that were much larger than those which could feasibly be paid during an experiment. Kahneman
and Tversky argued that the use of large, hypothetical outcomes produced a more valid assessment of performance than small, real outcomes because the outcomes were more representative of those risked in the real world.

Various measures have been used to quantify human decision-making in the laboratory. Some of these include: a) self-reported judgments of the attractiveness of a risk or gamble (e.g., a purchase or wager value) (Preston & Baratta, 1948; Lindman, 1971; Slovic, 1969b; Slovic & Lichtenstein, 1968a; Slovic & Lichtenstein, 1968b), b) preferences among options of a risk or gamble (Coombs & Pruitt 1960; Edwards, 1953; Edwards, 1954; Lindman, 1971; Miller, Meyer, & Lanzetta, 1969; Slovic, 1969a), and c) decisions to play or not (i.e., pass) on each trial (Mosteller & Nogee, 1951). Each of these measures has been used to test the effects of uncertainty on responding, yet different performances have been found depending on the measure that was used (Lichtenstein & Slovic, 1971; Lindman, 1971; Mellers, Chang, Birnbaum, & Ordóñez, 1992; Slovic, 1972; Tversky, Slovic, & Kahneman, 1990). This inconsistency, which is often referred to as preference reversal, has been shown to be a reliable finding especially among choice and attractiveness measures. In general, it is believed that differences in how a risk or gamble is presented to a participant directly influence how the outcome probabilities and values influence behavior (Tversky et al.).

Cognitive Models of Decision-Making

Most research on risky choice has been conducted by cognitive psychologists using the single-decision procedures described above. This research has revealed several important findings about human risk preferences, and various cognitive
decision-making models were developed to describe the results. Some of the most influential models are summarized below.

*Expected-value maximization.* Since the 18th century, expected value has been used to objectively quantify the value of a gamble (see Bernoulli, 1738/1954; Edwards 1955; Kahneman & Tversky, 1984; Krüeger, Daston, & Heidelberger, 1987). A common assumption has been individuals should prefer gambles that maximize expected value, a prediction known as *expected-value maximization,* (see Bernoulli, 1738/1954). This assumption is appealing because it assumes that decision-making is rational and predictable. That is, if behavior showed EV maximization then it should be solely determined by the outcome probability and size of the available options.

Since the first systematic investigations of the effects of outcome probability and size on preference for a gamble, however, it was clear that performance differed from EV maximization (Mosteller & Nogee, 1951; Preston & Baratta, 1948). Daniel Bernoulli (1738/1954) was one of the first to suggest that preferences that differed from those predicted by EV maximization probably served an adaptive function and were therefore not indicative of irrationality. Bernoulli supported his claim using an example known as the Saint Petersburg Paradox (first described by his cousin, Nicolas Bernoulli, in Montmort, 1713). The Saint Petersburg Paradox is a hypothetical gambling scenario in which a gambler is asked to report what they would be willing to pay for a gamble with the following conditions: a) each consecutive toss of a fair coin will result in either the end of the game, if heads lands up, or another coin toss, if tails lands up, b) and when heads lands up (and the game is ended) the gambler will be paid the amount of $2^f
where \( t \) equals the number of consecutive tails-up coin tosses that occurred prior to the last heads-up toss. Because the decreased likelihood of sequential tails-up tosses across trials is matched by a proportional increase in the outcome value, each subsequent toss has a constant and positive \( EV \). Because the possible number of consecutive tails-up tosses is infinite, the \( EV \) of this gamble is positive infinity. According to \( EV \) maximization, then, no wager value should be too high of a price to pay in order to play the gamble. Yet, Bernoulli concluded that no rational person would risk much of his or her total wealth to play the gamble.

This thought experiment demonstrated a limitation of \( EV \) maximization as a robust model of decision-making. Many subsequent experiments have confirmed that indeed risky choice is often inconsistent with predictions based on \( EV \) (e.g., Edwards, 1953; Preston & Baratta, 1948). Although Bernoulli and others effectively argued that \( EV \) maximization might not be a good predictor of human choice, researchers continue to describe preference among risks and gambles in relation to \( EV \) because it provides an objective standard against which preference can be compared.

**Subjective expected value.** Because \( EV \) maximization failed to provide an adequate description of human decision-making, several subsequent models of risky decision-making were developed in which the objective parameters of the \( EV \) model (amount and probability) were replaced with their subjective form. That is, in these models one or both of the objective \( EV \) parameters, outcome probability and size, were substituted with a subjective value, subjective probability and utility, respectively. Unlike outcome probability and size, which were based on objective characteristics of
the risk or gamble, subjective probability and utility were derived from participants' performance and were intended to indicate the subjective probability and size values on which their decision-making was based.

Preston and Baratta (1948) developed one of the first alternatives to $EV_{\text{maximization}}$. These researchers assessed participants' bids for 42 unique gambles and found that bid prices increased systematically with increased win size. However, participants usually paid too much for low probability gambles ($p = 0.05$ or less) and too little for higher probability gambles ($p = 0.25$ or greater). The authors suggested that bidding was not influenced by the gamble's stated probability, but instead was influenced by participants' subjective probability, a value that reflected a participant's estimate of the outcome probability. When objective probability in the $EV$ model is replaced with this subjective value, the result is the subjective expected value (SEV) model:

$$SEV = \sum (p_s \times A)$$

where $p_s$ is subjective probability. The SEV model had considerable appeal, as it was able to account for many deviations from rational responding (i.e., $EV_{\text{maximization}}$).

Expected utility. Another alternative to $EV_{\text{maximization}}$ resulted from studies that also showed decision-making was sensitive to the outcome size of a gamble, but not in the linear fashion predicted by $EV_{\text{maximization}}$ (see Bernoulli, 1738/1954; Mosteller & Nogee, 1951). Instead, it was often observed that small gains tended to be overvalued whereas large gains tended to be undervalued (see utility curves below). It was concluded that participants' irrational performance was a result of the difference
between the actual commodity values used and their subjective value, or the utility of that commodity to the participant. In other words, utility was what a commodity was worth to a particular person, and therefore it did not necessarily match the objective value of the commodity (e.g., its actual monetary value). The expected utility (EU) of an uncertain outcome was described as:

\[ EU = \Sigma (p * u) \]

where \( u \) is utility. Similar to the SEV model, the EU model was appealing because it maintained a rational view of human decision-making. That is, if behavior failed to maximize EV it was because behavior maximized EU.

Subjective expected utility. Both the SEV and EU models assumed that a process of subjective valuation occurs prior to decision-making, however, the subjective value used in each model was an objective value in the other, i.e., one model assumed that only probability was subjectively evaluated whereas the other assumed that only the commodity value was subjectively evaluated. According to Edwards (1953):

The situation is one in which one event (a choice) is determined by the interaction of two unknowns, probability and value as the S [subject] sees them.

It is obviously unreasonable to use either of the unknowns unless we know the value of the other unknown or can assume that it has been held constant. (pp. 363-364)

Because research had shown that both subjective probability and utility deviated systematically from their objective counterparts, several researchers argued that both outcome probability and size were subjectively evaluated during decision making.
(Edwards, 1954; Savage 1954; Siegel, 1959). The result was an integrated model of subjective probability and utility, called the subjective expected utility (SEU) model:

\[ SEU = \sum (p_s \times u) \]

From the 1950s to the 1970s, the SEU model dominated the analysis of decision-making behavior (e.g., Coombs & Komorita, 1958; Coombs & Pruitt, 1960; Lindman, 1971; Miller et al., 1969; Royden, Suppes, & Walsh, 1959; Slovic, 1969a; Slovic, 1969b; Slovic & Lichtenstein, 1968a; Slovic & Lichtenstein, 1968b; Tversky, 1967). Although the SEU model provided an accurate description of choice in many contexts, it did not allow predictions to be made \textit{a priori} (i.e., subjective weights must be determined from performance) and it was unable to account for several important patterns of risk preference, described below.

\textit{Prospect theory}. One unexpected finding from risky choice research was that choice tended to be risk averse when options were gains but risk prone when options were losses (Kahenman & Tversky, 1979). The SEU model was unable to account for this pattern. An alternative model called \textit{Prospect Theory}, was therefore proposed (Kahenman & Tversky, 1979). Prospect Theory was able to account for the shifts in risky choice across gains and losses and other choice patterns for which the SEU model had difficulty. These accomplishments were generally the result of adding several subjective and hypothetical elements to the SEU model (see Kahneman & Tversky, 1979; Kahneman & Tversky, 1982). According to Prospect Theory, numerous genetically endowed heuristics are employed during decision making that subjectively value each option for that person, at that time, in their current environment (for discussion on
heuristics and their possible neural mechanisms, see Hutchinson & Gigerenzer, 2005; Trepel, Fox, & Poldrack, 2005). After all options under consideration are subjectively valuated according to these heuristics, the person selects the one with the greatest expected value. Several of the most significant tenets of this approach can be illustrated with two sets of hypothetical choice problems (Kahneman & Tversky, 1979, p. 268). In each set, participants were asked to choose an option consisting of an outcome probability (if none is given, p = 1) and size from each of two paired options. The obtained proportion of responses for each option is shown in brackets:

Set 1:

A: $4000, 0.80 [20] or B: $3000 [80]

C: $4000, 0.20 [65] or D: $3000, 0.25 [35]

Set 2:

A’: -$4000, 0.80 [92] or B’: -$3000 [8]

C’: -$4000, 0.20 [42] or D’: -$3000, 0.25 [58]

It should be clear that Sets 1 and 2 contained identical options, except that in Set A outcomes were expressed as gains and in Set B they were expressed as losses, respectively. Within each set, the outcome values were the same from the first (A-B and A’-B’) to the second (C-D and C’-D’) pair, however, the probabilities in the second pair were exactly one fourth the probability as in the first pair, therefore expected value in the second pair was one-fourth the expected value as in the first pair.

In Set 1, when presented with a choice between options with certain or probabilistic gains (A-B) or two options with probabilistic gains (C-D), participants
showed a strong preference for the low-value, certain gain relative to the high-value, probabilistic gain in A-B, but preferred the high-value gain when both outcomes were similarly uncertain in C-D. The reverse pattern was observed when the same options were expressed as losses in Set 2. That is, participants preferred the high value probabilistic loss relative to the certain loss in A'-B', but preferred the low value loss when both outcomes were similarly uncertain in C'-D'.

The authors suggested that the responses on both Sets 1 and 2 indicated that participants tended to overweight options that produced certain rather than probabilistic outcomes (called the certainty effect). As such, it is likely that small changes in probability away from certainty ($p = 0$ or $1$) have a greater impact than larger changes at probability values further away from certainty (e.g., 0.2 to 0.8). The systematic reversal in preferences among Sets 1 and 2 demonstrated another central tenet of Prospect Theory, that preference among options that produce gains is opposite of preference among the same options presented as losses (called the framing effect). Specifically, preference among gains is risk averse and preference among losses is risk prone. Risk aversion is a preference for the option with the greatest probability whereas risk proneness is a preference for the option with the lowest probability. Therefore, when the options that produced risk-averse preference in A-B were changed to produce negative outcomes in A'-B', preference was risk prone. This pattern in preference was a primary factor that led to the rejection of the SEU model, which predicted risk aversion in all instances (see Kahneman & Tversky, 1979).
Prospect Theory, and its modified form Cumulative Prospect Theory (Tversky & Kahneman, 1992, for a review contrasting these models, see, Fennema & Wakker, 1997), like SEU, cannot be used to make a priori predictions about risk preferences. Nevertheless, it makes several unique predictions about behavior and appears to account for many violations of rationality. It therefore remains a leading model of risk sensitivity.

Methodological Limitations of Decision-Making Research for the Analysis of Gambling

As discussed above, the most common procedure for studying risk sensitivity in humans has been to present participants with single-decision tasks, using hypothetical, verbally-presented options. Although these procedures may model many one-shot risky decisions that occur in everyday life and have led to the development of several important accounts of risk sensitivity, including Prospect Theory, the many differences between these procedures and contingencies arranged by games of chance may limit the generalizability of the results to gambling.

Hypothetical commodities. Although both real and hypothetical commodities have been used in decision-making research, most studies have used the latter (see Weber et al., 2004). When hypothetical commodities are used, participants were typically instructed to respond as if the options produced real commodities (e.g., Kahneman & Tversky, 1982). The use of hypothetical commodities was encouraged by decision researchers, including Kahneman and Tversky. As described above, these authors suggested that using hypothetical, rather than real commodities was the most informative approach to studying decision making because it allowed researchers to
study choice for large, albeit hypothetical, outcome values. They also rejected the notion that using hypothetical commodities created any unique problems:

The reliance on hypothetical choices raises obvious questions regarding the validity of the method and the generalizability of the results. We are keenly aware of these problems. However, all other methods that have been used to test utility theory also suffer from severe drawbacks....Laboratory experiments have been designed to obtain precise measures of utility and probability from actual choices, but these experimental studies typically involve contrived gambles for small stakes, and a large number of repetitions of very similar problems. These features of laboratory gambling complicate the interpretation of the results and restrict their generality.

By default, the method of hypothetical choices emerges as the simplest procedure by which a large number of theoretical questions can be investigated. The use of the method relies on the assumption that people know how they would behave in actual situations of choice, and on the further assumption that the subjects have no special reason to disguise their true preferences. (p. 265)

Contrary to this argument, however, research has shown that performance sometimes differs depending on whether real or hypothetical outcomes were used (Weber et al., 2004), although this effect is somewhat inconsistent and depends on a number of other variables such as the type of procedures used to assess performance (Camerer & Hogarth, 1999). Overall, however, a main finding is that behavior tends to be more risk averse when outcomes are real compared to when outcomes are
hypothetical. This effect has been shown across studies in which both gains and losses have been investigated (Weber et al., 2004). Thus, studies that use hypothetical outcomes may not generalize to gambling in natural environments where outcomes are real money.

**Single-trial experimental tasks.** In many decision-making experiments, participants are given only single-trial exposures to gambles in order to assess performance. In gambling opportunities outside the laboratory, however, individuals are given repeated experience with the same gamble. Thus, the generality of data from single-trial studies to gambling may be limited. A likely reason for the use of single-trial procedures in decision research is that cognitive models, such as Prospect Theory, describe preference in terms of cognitive mechanisms rather than in terms of behavior-environment contingencies. Because it is assumed that mechanisms such as the certainty and framing effects are genetic traits (for a review, see Trepel et al., 2005), it is presumed that those processes will result in a similar decision on the first trial with a particular gamble as on subsequent exposures. Because choice is assessed on only a single trial, however, responding in these studies cannot be attributed to experience with a particular gamble, but only to pre-experimental experiences with similar options or to experiences with different gambles earlier in the experimental session.

What is particularly problematic for extending these studies to an analysis of gambling is that risk has been shown to vary systematically with experience on a particular risk or gamble. That is, risk preferences differ when options are presented only once compared to when they are presented repeatedly (Barron & Erev, 2003; Haw,
2007; Hertwig, Barron, Weber, & Erev, 2004; Hertwig & Ortman, 2001; Hogarth, 1981; Keren & Wagenaar, 1987; Ladouceur, Mayrand, & Touringy, 1987; Lopes, 1981; Rachlin, 1990; Weber et al., 2004; Wedell & Böckenholt, 1990). Keren and Wagenaar, for example, showed that preference for a gamble option on a single-decision procedure was modeled well by Prospect Theory (i.e., choice for gains was risk averse). However, when 10 consecutive choices on the same gamble were made, choice was more risk prone. One possible explanation for this effect is that the outcome experienced on each trial influenced choice on subsequent trials, which is not possible when choice is assessed on only a single trial. These results suggest that performance on single-decision procedures may not readily generalize to gambling in the natural environment because games are played repeatedly and performance on games of chance is likely influenced by the consequences of previous choices (i.e., few people sit down to play slot machines, blackjack, craps, etc. and only play a single trial, see Rachlin, 1990).

**Summary**

Research by experimental psychologists on human decision-making in situations of risk has provided important information about the relationship between behavior and uncertain events. The most common method of studying risk sensitivity has been to present participants with single choices between verbally-described hypothetical risks or gambles. Several normative models of choice have been developed using these procedures, and each has assumed that human choice is fundamentally rational. The failure of several models related to EV maximization led to the development of Prospect Theory, which remains a leading model of risk sensitivity among psychologists because it
makes several unique predictions about behavior and accounts for many violations of rationality. Although the single-trial methods used by experimental psychologists are valuable for understanding single choices in situations involving risk, the findings of these studies may not generalize well to gambling.

METHODS FOR STUDYING UNCERTAINTY: REINFORCEMENT-SCHEDULE RESEARCH

General Methods

Similar to economists and cognitive psychologists interested in risk, behavior analysts have also studied the effects of uncertainty on behavior by analyzing preference among options with varying probabilities and amounts (see Herrnstein, 1990a, 1990b). However, major differences in assumptions about the proper subject matter of psychology and causes of action have led behavior analysts to study risk using different procedures and to develop different interpretations of how variability affects responding. Behavior analysts, for example, assume that environmental contingencies, particularly the consequences of action, are the primary variables controlling behavior (Skinner, 1953). Thus, the behavior-analytic research methodology is characterized by repeated exposure to contingencies and repeated observations of behavior, and the use of real rather than hypothetical consequences. Researchers usually investigate responding by a small number of subjects over long periods of extended exposure to experimental conditions, often until behavioral stability is achieved (Cumming & Schoenfeld, 1960). Behavior is repeatedly measured under a particular set of conditions because responding often changes over time, especially following initial exposure to a particular contingency (Ferster & Skinner, 1957).
Reinforcement schedules. Early experimental analyses of behavior sought to determine how the schedule of reinforcement influenced responding (see Ferster & Skinner, 1957). Schedules of reinforcement define the set of requirements that relate reinforcer delivery to responding, the passage of time, or both. For example, ratio schedules define the quantity of responding that the subject must emit in order for a reinforcer delivery to occur. Alternatively, time schedules require only that a certain period elapse prior to reinforcer delivery. Interval schedules specify that responding will only produce a reinforcer if a response occurs after a certain period of elapsed time. Schedules for reinforcer delivery can be arranged such that the response or interval requirements are fixed (e.g., Ferster & Skinner, 1957), variable (e.g., Ferster & Skinner, 1957), random (e.g., Millenson, 1963; Sidley & Schoenfeld, 1964), progressive (e.g., Hodos & Kalman, 1963), et cetera. Research has shown that the schedule type and requirement directly influence the rate and patterns of responding (Ferster & Skinner, 1957).

Operant psychologists first investigated the effects of uncertainty on behavior by examining performance on variable schedules of reinforcement and comparing it to performance on fixed schedules. With fixed schedules, such as fixed-ratio (FR) or fixed-interval (FI) schedules, a constant number of unreinforced responses or a constant period of non-reinforcement, respectively, follows each reinforcer. Alternatively, with variable schedules, such as such as variable-ratio (VR) or variable-interval (VI) schedules, a variable number of unreinforced responses or a variable period of non-reinforcement, respectively, follows each reinforcer (see also constant-probability VI schedules, Catania
& Reynolds, 1968; Fleschler & Hoffman, 1962). A main finding of this research was that variable schedules (both VI and VR schedules) produce higher rates of responding than fixed schedules (see Catania & Reynolds, 1968; Farmer, 1963).

Catania and Reynolds (1968), for example, showed that when pigeons key-pecked for grain access, FI schedules tended to produce far lower response rates than comparable VI schedules. This finding, the authors speculated, was a result of the predictable nature of reinforcer delivery generated on the FI schedule. That is, the subjects eventually learned that reinforcement never occurred immediately following a reinforcer delivery, and thus responding after reinforcement was very low. The low rates of responding after reinforcement was described as a post-reinforcement pause (also called inter-reinforcement interval pause, Mazur, 1983). Catania and Reynolds noted:

The FI schedule includes discriminable periods of time during which the local rates of reinforcement, as inferred from performance, is or at near zero.... Such performance, which results in a large proportion of time when low rates of responding occur during each interval, produces an overall rate of pecking lower than that maintained by a schedule that provides no discriminable periods of nonreinforcement [the VI schedule]. (p. 369)

Other studies have shown a similar effect using intermittent ratio schedules. That is, VR schedules tend to generate higher rates of continuous responding compared to FR schedules (Ahearn & Hineline, 1992; Field, Tonneau, Ahearn, & Hineline, 1996). This effect may be partially due to the post-reinforcement pausing that occurs on FR
schedules (Felton & Lyon, 1966; Powell, 1968). The cyclical periods of low response rates following reinforcement on both FI and FR schedules are likely a result of the predictable nature of the schedule requirements. However, some studies have also shown that VR schedules maintain higher rates of responding (and generate greater preference) because some reinforcers are produced with very short delays to reinforcement (i.e., since the previous reinforcer) compared to those delays produced on an FR schedule with an equal mean rate of reinforcement (Field et al., 1996) (see below).

Researchers have also investigated the effects of uncertainty on behavior using random schedules. Random schedules differ from variable schedules in that reinforcer delivery is determined probabilistically. For instance, reinforcer delivery on a random-time (RT) schedule is accomplished by repeatedly sampling a random number generator at regular intervals. A similar procedure is used for response-contingent random schedules, such as random-ratio (RR) and random-interval (RI) schedules in which the probability of reinforcement is determined probabilistically after each response or after fixed time intervals, respectively. Random schedules tend to generate similar or slightly higher response rates than equivalent variable schedules, and like VI or VR schedules they generate much higher rates than fixed schedules (e.g., Madden, Dake, Mauel, & Rowe, 2005).

Reinforcement-schedule research has therefore indicated that variability in reinforcement increases the rate of responding and results in different patterns of responding compared to fixed schedules. Skinner (1953) argued that most games of
chance on which humans often gamble are programmed using VR schedules of monetary reinforcement, and concluded that the qualities of VR schedules were at least partially responsible for the high rates of responding produced by these games. As with the schedule research using non-human subjects, researchers have investigated the effects of many types of reinforcement schedules on responding in human participant, often by having participants respond on simple tasks that produce monetary outcomes according to fixed or variable schedules (e.g., Pietras, Brandt, & Searcy, 2010). Although researchers eventually concluded that games of chance actually operate on RR schedules, VR and RR schedules have been shown to produce similar response patterns in humans (see Hurlburt, Knapp, & Knowles, 1980) and behavioral psychologist interested in gambling have continued to explore the role of these and other unpredictable ratio schedules on responding on games of chance (Weatherly & Brandt, 2004).

*Concurrent schedules of reinforcement.* Another method used by operant psychologists to study the effects of variability on behavior has been to analyze responding on concurrent schedules of reinforcement. One benefit of concurrent-schedule research over single-schedule research is that preference for one option over another can provide a precise and sensitive measure of the effects of variability on the value of a consequence as a reinforcer. On a concurrent schedules procedure (see, Catania, 1969), two or more schedules are simultaneously available and each is programmed on a separate operandum (Skinner, 1962). Similar to single-schedule procedures, on current schedules both the rate and pattern of responding on each
schedule can be assessed. However, because multiple response options are simultaneously available, preference among the available schedules can also be measured. On free-operant procedures (in which responding can occur continuously), preference may be measured by relative response rates (see free-operant responding, e.g., Ferster, 1957; Herrnstein, 1961; see also concurrent-chains procedure, e.g., Herrnstein, 1964) and in discrete trial procedures preference is measured by the proportion of choices for each response alternative (e.g., Mazur, 1984) (see also Grace, 1996, for a discussion on the relatedness of these measures).

In a free-operant concurrent-schedules procedure, the effect of uncertainty on reinforcer value has been studied by presenting subjects with choices between two intermittent schedules (e.g., Davison, 1982). Preference on these tasks is measured by the relative response rates on the available alternatives. A variant of this procedure is a free-operant concurrent-chains procedure, in which each operandum is programmed to produce reinforcers according to an independent chain schedule, each of which has an initial- and terminal-link schedule (e.g., Herrnstein, 1961; Killeen, 1968). During the initial link, responding can be freely distributed between the alternatives until one schedule requirement is completed. Completing one initial-link schedule disables the other schedule and produces the terminal link schedule. Responding on the terminal link schedule produces primary reinforcement. In other words, this procedure involves concurrently available schedules during the initial link (i.e., choice period), but only a single schedule is active during the terminal link (i.e., consequence period) (Mazur, 2006). Because concurrent schedules are active only during the initial link, preference
on this procedure is generally assessed as the relative response rates during the initial
link.

One problem with studying variability using free-operant schedules is that
programmed differences in the rate of reinforcement may also result in differing delays
to reinforcement (see Mazur, 1984). Thus, researchers have also studied choice using
discrete-trials procedures in which a single response to one option disables the
alternative and produces the reinforcer after a programmed delay (e.g., Mazur, 1984).
Because the researcher controls the trial duration and reinforcer delivery, the delays to
reinforcement following a response can be precisely controlled. Given that choice
responding is limited to a single period during each trial, the proportion of choices made
for an alternative indicates preference in this procedure.

Behavioral Models of Preference

A main finding of studies investigating preference on free-operant concurrent VI
VI schedules was that responding tended to be distributed according to the relative rate
of reinforcement (de Villiers & Herrnstein, 1976; Herrnstein, 1961; Herrnstein, 1979),
and in some studies, the magnitude (Catania, 1963; Catania, 1969), on the available
alternatives. That is, the proportion of responding generated by any one schedule was a
function of the frequency or magnitude of reinforcement on that schedule relative to
the total available reinforcement. This general pattern is called matching and has been
shown across numerous species (Baum, 1979; de Villiers & Herrnstein, 1976). Matching
is also found with concurrent VI VR (Herrnstein & Heyman, 1979; McSweeney, Murphy,
& Kowal, 2001), and concurrent VR VR schedules (MacDonall, 1988). A different finding
occurs when participants are given choice between fixed and variable options, such as concurrent Fl VI (Davison, 1982; Killeen, 1968) or FR VR (Ahearn & Hineline, 1992) schedules. Under these conditions, preference tends to be stronger for variable that fixed schedules even with longer means (i.e., lower reinforcement) on the variable option.

Herrnstein (1961) proposed that the pattern of pigeons’ key pecking for food reinforcers on concurrent VI VI schedules procedure could be accounted for by a simple equation known as the Matching Law:

\[
\frac{B_1}{B_1 + B_2} = \frac{R_1}{R_1 + R_2}
\]

where \( B \) is the rate of responding, \( R \) is the rate of reinforcement, and the subscripts (1 and 2) indicate the available response alternatives. In this model, the proportion of total responding on an alternative equals the proportion of total reinforcement delivered on that alternative. Although the simplicity of this model and its reliance on only observable parameters makes it conceptually appealing, it is limited in two important ways.

First, like EV maximization, the Matching Law predicts a linear relationship between responding and reinforcement, however, behavioral studies of choice often indicated that behavior deviated slightly from this prediction (see Baum, 1979). To address this limitation, Baum (1974) proposed adding two free parameters to the Matching Law, which resulted in the Generalized Matching Law (GML):

\[
\frac{B_1}{B_2} = k \left( \frac{R_1}{R_2} \right)^a
\]
where the free parameters, $a$ and $k$, indicate sensitivity and bias, respectively. When plotted as:

$$\log (B_1/B_2) = a \log (R_1/R_2) + \log k$$

$a$ is the slope and $k$ is the $y$-intercept of the line fitted to the function between responding and reinforcement. Undermatching and overamatching performances (i.e., deviations from perfect matching) can be described by the GML by using $a$ less than or greater than 1, respectively. Similarly, uncontrolled preference for one option (i.e., bias) can be described by using $k$ less than or greater than 1. Note that perfect matching occurs when $a$ and $k$ equal 1, a condition that makes the GML reduce to the original Matching Law (for an alternative model of choice, see Baum & Davison, 2009).

The second limitation of the Matching Law is that it failed to adequately predict performance on concurrent-chains and discrete-trial procedures that involve choices between delayed reinforcers (Fantino, 1969; Herrnstein, 1964; Mazur, 1984; Squires & Fantino, 1971), which tended to show greater preference for variable delays than for fixed delays (Davison, 1969; Fantino, 1967; Killeen, 1968). Several models have been developed to account for the influence of delayed reinforcers on choice (see contextual-choice model, Grace, 1994; see hyperbolic value-added model, Mazur, 1991; see delay-reduction hypothesis, Preston & Fantino, 1991). These models tend to make somewhat similar predictions to one another because each adjusts the reinforcement value that enters into the Matching Law model according to one or more delay parameters.

On discrete-trial procedures, reinforcer value ($V$) is well described by a simple form of the hyperbolic-decay model (Mazur, 1984):
\[ V = \frac{A}{1 + KD} \]

where \( A \) is reinforcer value with zero delay, \( D \) is the delay duration, and \( K \) is a free parameter for the rate of value decay due to the delay. The hyperbolic nature of this model indicates that initial reinforcer delays above zero have a far greater reductive effect on value than similar increases at longer delays. For example, if \( A \) and \( K \) are assumed to be 1 in the above model, an increase in delay from 0 to 1 sec reduces \( V \) from 1 to 0.5, whereas an increase in delay from 9 to 10 sec only reduces \( V \) from 0.11 to 0.10.

The hyperbolic-delay model has been shown to accurately describe non-human choice on discrete-trial procedures (see Mazur, 2006, for a review). In many studies, it has also been demonstrated that the hyperbolic-decay model describes much of the variance in human choice under similar conditions (e.g., Lane, Cherek, Pietras, & Tcheremissine, 2003; Madden et al., 2004; Yi, de la Piedad, & Bickel, 2006) A common finding among non-human subjects (Davison, 1969; Essock & Reese, 1974; Mazur, 1984) is a strong preference for options that produce reinforcement with variable delays compared to fixed delays. A similar pattern, however is not seen in human subjects when outcomes are conditioned reinforcers (see Kohn, Kohn, & Staddon, 1992; Pietras & Hackenberg, 2001) but is obtained in studies using more consumable reinforcers (e.g., Locey, Pietras, & Hackenberg, 2009). The hyperbolic-decay model predicts preference for variable over fixed schedules because a lower reinforcement value is assigned to a reinforcer with a fixed delay than with variable delays with an equal mean. For example, if \( A \) and \( K \) are again assumed to be 1 in the hyperbolic-decay model and a reinforcer with one of two possible delays occurs on one alternative, e.g., 1 or 9 sec (this is the
simplest case of a variable schedule), and the delay on the other alternative is fixed and
equal to the mean delay on the variable alternative, i.e., 5 sec, then the mean
reinforcement value \( V \) is much smaller on the fixed (0.17) than on the variable (0.30)
alternative. Numerous studies have shown that the hyperbolic-decay model predicts
preference for variable delays across wide delay distributions (see Mazur, 2006).
Although this pattern is often called preference for variability, it may be more accurate
to describe this pattern as a disproportionately strong preference for schedules that at
least occasionally deliver short reinforcement delays.

In a few behavioral studies of choice, the effects of reinforcer uncertainty on
behavior was also studied using random schedules that produce reinforcers
probabilistically and several models have been developed to account for choice of
probabilistic reinforcers (e.g., Mazur, 1984; Rachlin, Castrogiovanni, & Cross, 1987).
These models generally assume that decreasing the probability of reinforcement below
1 has a similar effect on responding as increasing delay above zero seconds. That is, in
these models the value of a reinforcer that is delivered probabilistically is adjusted in a
similar fashion as a reinforcer that is delayed. Mazur, for example, included
reinforcement probability in the hyperbolic-decay model so that probabilities less than 1
reduced reinforcer value proportionately. The result was a generalized hyperbolic-decay
model (Mazur, 1984; Mazur, 1989):

\[
V = \sum p \left[ \frac{A}{1 + KD} \right]
\]

where \( p \) is reinforcer probability associated with a particular delay. Notice that when the
delay is zero, then \( p \) is 1, and \( V = EV \). Thus, the behavioral models of choice can be
summarized as describing matching the expected value of the possible reinforcers given
the hyperbolic-discounting effects of delay on value.

Several studies have shown that models like generalized hyperbolic-decay
provide a good description of choice for probabilistic reinforcers (Mazur, 1985; Mazur,
1989; Mazur, 1991). However, other studies have indicated that probabilities are not
equivalent to delays. For instance, Green, Myerson, and Ostaszewski (1999) showed
that human participants discounted delayed and probabilistic hypothetical amounts of
money differently when large and small amounts were used.

Methodological Limitations of Reinforcement-Schedule Research for the Analysis of
Gambling

The many differences between the contingencies arranged in nonhuman choice
studies and those found in natural gambling environment complicate extensions of
operant research to real-world gambling. One difference is that much of the research by
operant psychologists on choice under uncertainty was conducted with non-human
animal subjects using primary reinforcers (food) in simplified environments. Whether
the results generalize to human responding for conditioned reinforcers in complex
gambling environments is therefore unclear. Results of several studies indicate
however, that nonhuman research on risk is relevant to human performance. For
example, studies have shown that conditioned and generalized reinforcers (e.g., tokens
exchangeable for money) generate similar patterns of behavior as primary reinforcers
(e.g., Hackenberg, 2009) and reinforcer delays have similar effects in human and non-
human subjects when choice in humans is studied with more immediately consumable
reinforcers (see Locey et al., 2009; Madden et al., 2005; Madden, Ewan, & Lagorio, 2007; Madden, Petry, & Johnson, 2009).

A second difficulty in generalizing results from operant schedule research to gambling is that relative response rate, which is the most common measure of preference in free-operant risky-choice studies, may not be particularly relevant to performance on most games of chance. Unlike free-operant procedures, games of chance operate very similarly to the discrete-trial procedures in that they allow responding only during specific periods. Specifically, wagers on a game of chance can only be made at certain times that are clearly signaled during game play. The inter-trial intervals vary across different games of chance, for instance, games such as slot machines and most video-based games allow relatively frequent responding, whereas games such as keno or par-mutual betting allow only infrequent wagering. Because all games of chance place some restrictions on when responding is available, however, performance is not readily analyzable in terms of response rate (for a discussion on the influence of inter-trial intervals on responding, see Mazur, 2001).

Another problem in applying results of operant studies on risky choice to gambling is that most operant studies do not program wagers or losses of reinforcers. This problem is primarily due to practical limitations of arranging an initial wager (i.e., response cost) for non-humans when the reinforcer is food or another primary consumable reinforcers. As a result, no studies with nonhumans have investigated the influence of wagering on risk preferences. Research on token reinforcement, however, has shown that responses in non-human subjects may be maintained by presentations
of token reinforcers (e.g., lights or tokens paired with food) and punished by token removal (e.g., Raiff, Bullock, & Hackenberg, 2008; Yankelevitz, Bullock, & Hackenberg, 2008). Such a token procedure could also be used to study wagers in nonhumans, which may improve the generalizability of animal models of gambling (see Kendall, 1987; Madden et al., 2007).

Finally, operant studies have most often studied variability in the form of reinforcer probability and delay instead of reinforcer amounts. This characteristic is considerably different from cognitive studies on variability and from most real-world games of chance that produce gains of varying reinforcer amounts with different probabilities. Variability in reinforcer amount or probability tends to produce risk-averse preferences in humans (e.g., Kohn, Kohn, and Staddon, 1992; Lane & Cherek, 2000; Pietras & Hackenberg, 2003) and nonhumans (Barnard & Brown, 1985) whereas variability in reinforcer delay tends to produce risk-prone choices in humans (Pietras & Hackenberg, 2001) and nonhumans (see Kacelnik & Bateson, 1996). Although some researchers have conceptualized probabilistic reinforcement as delayed reinforcement (Rachlin, Logue, Gibbon, & Frankel, 1986), as described above, research has shown that delay and probability are not entirely equivalent.

Summary

The methods used by operant psychologists to study the effects of uncertainty on behavior differ in several important ways from those used by cognitive psychologists, for instance, outcomes are experienced instead of verbally described, behavior is studied across repeated exposure to outcomes, and consequences tend to be real
rather than hypothetical. Operant research has provided important information about
the influence of variability on responding. This research has shown that variable
schedules generate greater preference and higher response rates than fixed schedules,
that delays to reinforcement produce a predictable reduction in reinforcer value, and
that non-human subjects prefer variable over fixed delays to reinforcement. This
research has also shown that when humans and nonhumans are given choices between
fixed and variable amounts, choice tends to be risk averse. Nonetheless, the lack of
wagers, the limited outcomes on choice tasks, and the greater emphasis on variability in
delays than variability in reinforcer probability or amount limits the generalizability of
much operant research to gambling.

SIMULATED-GAMBLING RESEARCH

General Methods

Given the many differences between the contingencies programmed on games
of chance and those typically arranged in laboratory studies of choice under uncertainty,
some researchers have begun to use simulated games of chance to study gambling
behavior more directly under laboratory conditions.

Although apparatuses analogous to real-world gambles have a long history of
use in studies on preference (see Hurlburt et al., 1980; Lewis & Duncan, 1956; Murray
1971), studying gambling using simulated games of chance was relatively uncommon
prior to the development of several computerized games that could be easily (and
legally) used in a laboratory setting. These simulations include: video-poker simulations,
Dixon, MacLin, & Hayes, 1999; roulette simulations, Machlin & Dixon, 2004; and slot-
machine simulations, MacLin, Dixon, & Hayes, 1999. These simulations allowed researchers a high degree of control over various parameters of the gambling game, including the type of game, the number of game options, wager amounts, the range of possible winning outcomes, and winning outcome values. Using these procedures, behavioral researchers have investigated the effects on gambling of numerous environmental variables, such as percentage payback (see Brandt & Pietras, 2008; Schreiber & Dixon, 2001; Weatherly & Brandt, 2004), token value (Weatherly & Brandt, 2004), reinforcement frequency (see Dixon, MacLin, & Daugherty, 2006), near-miss frequency (see Kassinove & Schare, 2001; MacLin, Dixon, Daugherty, & Small, 2007), the frequency of a “big win” (see Kassinove & Schare, 2001; Weatherly, Sauter, & King, 2004), and the participant stake (see Weatherly, McDougall, & Gillis, 2006).

Simulated-gambling procedures. On simulated gambling tasks, the outcome probabilities are determined by sampling a random number generator following each response, (i.e., a RR schedule) or are predetermined to yield a RR schedule of a specific value. Simulated-gambling procedures can be categorized according to the type and number of response options available to the participant. Gambling has most often been studied by instructing participants that they may gamble on a single gamble option for a certain amount of time and that they may quit gambling at any time during a session (e.g., Brandt & Pietras, 2008; Weatherly & Brandt, 2004; Weatherly, Sauter, & King, 2004). This procedure may be described as a single-option gamble procedure because there is only one response option available, the gamble. For example, Weatherly and Brandt (2004) staked participants with points exchangeable for money, which could be
gambled on a single-option simulated slot machine. Across two experiments, the effects of \( PP \) (75\%, 83\%, and 95\%) and point value ($0.00, $0.01, and $0.10) on gambling was investigated. The results showed that fewer wagers were made as the point value increased, however, no effect of \( PP \) on gambling was found.

One problem with single-option gamble procedures is that participants are not required to gamble so individual differences in gambling (e.g., number of bet placed) can influence participants' exposure to the experimental conditions. That is, participants who quit early may not experience the same contingencies as other participants. To better control participants' exposure to the independent variables, researchers have used procedures that require participants to gamble during part of a session (usually the start of a session), and quitting is not provided as an explicit option (see Dixon, 2000; Dixon, Hayes, & Aban, 2000; Dixon et al., 2006; Dixon & Schreiber, 2002; Kassinove & Schare, 2001; MacLin et al., 2007; Schreiber & Dixon, 2001). This type of \textit{forced-gamble} procedure increases the consistency between participants' experience with the experimental contingencies and the programmed contingencies, and therefore may improve the internal validity of some investigations.

Researchers have also combined these two methods. Schreiber and Dixon (2001), for example, instructed participants to gamble 50 times on a single-option simulated slot machine with points (exchangeable for entries into a cash lottery) given to them by the experimenter, after which they could quit gambling at any time. The \( PP \) of the machine during the initial 50 forced trials was varied across three conditions (40\%, 80\%, and 120\%) but was 0\% (i.e., extinction) during the free-gambling phase that
followed. This manipulation had no significant effect on either the number of trials played during extinction or on response latencies between the end of one gamble and a subsequent wager during forced trials, however, it was found that the latter was far greater following wins than losses, a similar pattern of post-reinforcement pausing as seen in non-human subjects.

An alternative to the single-option approach is to present participants with multiple gamble alternatives available concurrently (Dixon et al., 2006; MacLin et al., 2007). Similar to the discrete-trials procedures, concurrent-gambles procedures can be used to arrange two simultaneously available independent gamble options. Like the single-option procedures, however, concurrent-gambles procedures used to date have not provided an alternative to gambling and participants are simply instructed to play until the session terminates (see Dixon et al., 2006).

*Limitations of current simulated-gambling procedures.* Despite the greater similarity between contingencies generated in simulated-gambling procedures and those found in real-world gambling, there still remain many differences between these simulated gambling tasks and contingencies found in natural gambling environment. One difference between gambling simulations and casino games is that researchers have made wagering possible by giving the participants points or tokens at the start of a session so that they are not required to gamble with their own money. The practice of staking participants with “house money” has been criticized because participants may show elevated levels of risk taking when they gamble with staked rather than earned money (see Madden et al., 2007; Weatherly & Phelps, 2006). Support for this has come
from risky-choice research (Gärling & Romanus, 1997; Hollenbeck, Ilgen, Phillips, & Hedlund, 1994; Thaler & Johnson, 1990; Weber & Zuchel, 2005), and on one case gambling research (Ladouceur, Gaboury, Bujold, Lachance, & Tremblay, 1991).

For example, Thaler and Johnson (1990) presented participants with two-stage decision problems that involved an initial hypothetical gain or loss of money after which the participant was asked to make a risky choice with their own money (note, however, that participants were deceived to believe that they could lose their own money and no actual losses occurred). Across all conditions, participants showed strong risk proneness in the second stage if they had experienced a gain in the first stage compared to when they experienced a loss. That is, choice was risk prone when participants were risking house money (i.e., prior gains). The authors suggested that this pattern occurred because the potential loss in the second stage was less aversive when it was a loss of money they had won compared to when it was a loss of their own money (money brought to the experiment by the participant).

Ladouceur et al. (1991) showed a similar effect between gambling on a video-poker machine in a laboratory and a grocery store (a legal form of gambling in Quebec, Canada). Participants were all regular gamblers that failed to meet criteria for pathological gambling. Participants were matched to groups based on the mean amount bet each week. Those in the laboratory condition were staked with an amount of money equal to this value whereas in the natural setting participants could gamble with their own money up to this value. The results indicated that participants wagered significantly more money in the laboratory than in the natural setting. Together, these studies
showed that risk varied depending on whether participants risked their own or the experimenter’s money.

Another difference between gambling simulations and casino games is the number of response options available. As described above, in the laboratory, gambling is often studied using single-option procedures in which participants are instructed that they may gamble on the experimental task for a certain amount of time and that they may quit gambling at any time during a session. Participants can only earn money, however, by responding on the gamble option. Outside the laboratory, a gambler has many available gamble and non-gamble response options that may produce reinforcement. Using only a single option may therefore produce levels of gambling that may not be observed under circumstances that are more naturalistic. For example, participants may persist on an unprofitable option (i.e., a gamble option) much longer than would occur if multiple response options were available. Even on concurrent-gamble procedures, participants are generally not allowed to quit at any time (and still receive compensation) and only gamble options are made available. Thus, as with the single-option procedures, gambling is the only response that will produce reinforcers.

Simulated gambling procedures may also arrange unintentional demand characteristics that influence gambling (Weatherly & Phelps, 2006). Demand characteristics describe the characteristics of a procedure that may potentially inform the participant about the experimental goals (Orne, 1962). In single-option gamble procedures, for example, participants are given only one option and are instructed that they may gamble for some period during the session. However, because participants
know they are in a laboratory study on gambling, they may believe the experimenter
does not view quitting as a desirable response and therefore they may place more bets
then they would under similar conditions outside the laboratory.

In summary, the use of a participant stake and the limited response options
given to participants raise concerns about the ecological validity of the results from
experiments using gambling simulations. Although simulated-gambling procedures offer
many advantages to single-operant and concurrent-schedules procedures, few
researchers have continued to develop these tasks to better model gambling in the
natural environment. By better simulating real-world gambling environments,
researchers may improve their ability to predict and modify gambling outside the
laboratory.

Concurrent Gamble No-Gamble Procedure

A gambling procedure that may better simulate natural gambling contingencies
in a laboratory context and that offers several methodological improvements over
existing gambling procedures is a concurrent gamble no-gamble procedure. This task
could program two independent and simultaneously available options: a gambling
option and a non-gambling option. Thus, unlike previous single-option and concurrent-
gambling procedures, a gamble option would always be available but gambling would
not be required. This approach is similar to the concurrent-gambles procedures, with
the primary difference that at least one option does not involve gambling.

An important advantage of a concurrent gamble no-gamble task is that it may
not place the same demand characteristics on gambling as single-option or concurrent-
gambles tasks. In natural gambling environments, people are rarely obligated to gamble and they have numerous no-gamble response options available (eating, drinking, conversing, observing others, walking around, etc.). In concurrent-gambles procedures, however, participants would not be required to gamble (see Weatherly & Phelps, 2006). Quit options are typically given to participants during single-option procedures, but very few participants quit a session without gambling (Weatherly et al., 2006). Such findings suggest that participants may have certain expectations about how their performance will be evaluated, for example, they may believe that quitting a session or the experiment, at least immediately, is not a desirable outcome for the experimenter. As described above, if simulated gambling procedures produced such expectations, gambling in laboratory studies is likely elevated compared to the levels found in the natural environment. Because a concurrent gamble token-production procedure can be programmed to deliver reinforcement on both options, it may reduce demand characteristics and produce gambling patterns that are more comparable to those outside the laboratory.

Another important benefit of a concurrent gamble token-production procedure compared to single-option procedures, is that it may better assess the sensitivity of gambling to reinforcement and punishment contingencies, including the size and frequency of gains and losses. Numerous studies with non-human subjects have shown that behavior tends to be relatively insensitive to changes in reinforcement variables, such as reinforcer magnitude, when responding is measured using single-schedule procedures, whereas behavior tends to be more sensitive to the same manipulations
when measured using a concurrent-schedules procedure (for a review see Bonem & Crossman, 1988). For example, Catania (1963) showed that pigeon’s rates of key pecking were insensitive to changes in reinforcer duration when duration was manipulated across conditions on a single variable-interval (VI) schedule, but that responding was more sensitive to reinforcer duration when duration was manipulated on one option of a concurrent VI VI schedule. A similar finding has been reported in studies investigating the effects of reinforcer size and probability on gambling. Brandt and Pietras (2008) found that gambling was generally insensitive to changes in win size and frequency when participants were exposed to a single-option gambling procedure, whereas Dixon et al. (2006) showed that behavior was sensitive to these variables when participants were exposed to a concurrent-gambles procedure. Together, these findings suggest that concurrent-schedules procedures may provide a more sensitive measure of the effects on gambling of changes in gains and losses compared to single-option procedures.

A third methodological improvement made possible by the concurrent gamble no-gamble procedure is that it can eliminate the need to use a participant stake. As described above, an important difference between gambling on laboratory simulations versus gambling under naturalistic conditions is that in the laboratory, participants gamble with tokens or money given to them by the experimenter. That money is given freely to participants may influence levels of gambling. In a concurrent task, an option that delivers response-contingent tokens could be programmed concurrently with the gamble option. Participants could use the tokens earned on the no-gamble option as a stake for the gambling option. This procedure would allow the participant to earn
tokens within a session and to gamble only those tokens earned or won by responding on the gamble option. This procedure minimizes ethical concerns of allowing participants to gamble with their own money because potential losses are limited to the amount earned during the task. At the same time, this approach better models real-world gambling because it requires that individuals wager money they have earned rather than money that has been given to them.

In summary, a concurrent gamble no-gamble task may have several advantages over other gambling simulations in that it may better model important features of natural gambling environments. One primary goal of this project was to develop and test a concurrent gamble no-gamble task and compare gambling on this new procedure to gambling on existing procedures. The laboratory procedure that was developed for this project was a non-computerized card game. The experimenter served as the dealer and the participant was repeatedly offered choices between a no-gamble and a gamble option that could produce tokens exchangeable for entries into a $50 lottery. This type of “in person” simulation has been used in other simulated gambling studies (e.g., Dixon, 2000), but is less common than computer simulations because of the greater resources needed to record and quantify responding (see Weatherly & Phelps, 2006). This non-computerized game was used in part because it allowed rapid changes in experimental contingencies, was simple to arrange, and had face validity (i.e., many casino games involve cards). To minimize the possibility that a participants’ experience with a particular game would influence responding (see Haw, 2007), the task was a novel card game (designed by the experimenter) that did not closely resemble any
common casino game. The card game modeled important characteristics of gamble contingencies discussed above and allowed the experimenter to control the outcome probabilities and magnitudes.

**SUMMARY AND RATIONALE**

Psychologists have had a longstanding interest in studying choice under conditions of uncertainty, yet most decision research has not directly focused on the analysis of gambling. Both human decision-making research and behavioral research on intermittent reinforcement schedules has made valuable contributions to our understanding of the effects of uncertainty on responding, however, the procedures used in these studies do not closely model real-world gambling contingencies. As a result, the extent to which the findings of this research directly inform the analysis of gambling is unclear.

Operant psychologists have recently developed several computer simulations of common casino-style games of chance that have allowed researchers to better model gambling contingencies. Nevertheless, the contingencies arranged by these procedures still differ in several respects from gambling contingencies found outside the laboratory. For example, in these procedures participants are staked with tokens prior to experimental sessions and participants are only presented with gambling response options. These features may inadvertently increase the likelihood of gambling. The main goals of the present research were to (a) investigate whether the number of response options or the participant stake influence gambling, and (b) examine behavior
under new experimental task that presented participants with concurrent gamble and no-gamble response options.

Four experiments were conducted. Three experiments compared gambling across conditions in which (a) a no-gamble option was or was not concurrently available with a gamble option (Experiments 1 and 2), and (b) a stake was or was not given to participants prior to experimental sessions (Experiment 3). Experiments 2, 3, and 4 also examined the extent to which the reinforcement magnitude (i.e., number of tokens) produced on the no-gamble option influenced gambling. These experiments helped to determine whether methodological features of typical laboratory gambling procedures influenced gambling and evaluated the utility of the new concurrent gamble no-gamble procedure.

EXPERIMENT 1

Laboratory gambling procedures that only provide participants with a gambling option may not provide an accurate assessment of gambling because they do not closely model options available to the gambler in the natural environment. First, participants in gambling studies are usually given instructions to respond or to earn as much as possible (see Weatherly et al., 2004), but no alternative to gambling is available. Thus, experimenter demand may inflate gambling levels. Second, gamblers typically have many choice alternatives that do not involve gambling, so responding on procedures in which gambling is the only option may not closely resemble real-world gambling conditions. By providing an alternative no-gamble response option, the concurrent gamble no-gamble procedure described above may provide a better assessment of
gambling. To date, no study has compared gambling on a gambling-only procedure and concurrent gamble no-gamble procedure. If the concurrent gamble no-gamble procedure indeed produces fewer demand characteristics than the single-option procedure, it would be expected that reduced levels of gambling would be observed.

Experiment 1 was therefore designed to compare gambling on a single-option gambling procedure to gambling on a concurrent gamble no-gamble procedure. On the standard procedure, on each choice trial participants could choose the gamble option or choose to quit the game (Quit condition), whereas on the gamble no-gamble procedure participants could choose the gamble option or an option that simply progressed the game to the next trial (Pass condition). In the Quit condition, a single response to the quit option terminated the session. In the Pass condition, a response to the pass option resulted in a 45-s timeout followed by the next trial. Across conditions, responses on the quit and pass options produced the same net reinforcement (0 tokens). This investigation was designed to examine whether equivalent levels of gambling would be generated when the participant could only gamble or could choose among a gamble and no-gamble (pass) option. It was hypothesized that the number of gambles would be greater in the single-operant (Quit) condition than in the concurrent-operant (Pass) condition.

Method

Participants. Twenty participants (14 females, 6 males) aged 18-21 (M = 18.8 years) were recruited via flyers posted at Albion College. The flyers invited male and female students to participate in a study on decision making for course credit and a
chance to win $50. Participants were informed that each token earned during their participation was equivalent to one entry into a $50 lottery and that one lottery winner was chosen from every 10 participants in the experiment.

**Setting and apparatus.** Experimental sessions were conducted in a sound attenuated experimental room (2 m x 2 m x 2.6 m). The room contained a desk, personal computer, digital video camera, game table, two chairs, and several lamps. The game table (1.02 m long, 0.76 m wide, and 0.76 m high) was positioned perpendicular to the desk (2 m x 0.6 m x 1.4 m). Items used to play the game included bridge-sized playing cards (Hoyle Super Jumbo Index), game chips (4 cm in diameter), and a choice marker (a 5 cm x 5 cm x 5 cm glass cube). The digital video camera (mounted on a tripod) was positioned on the desk and was pointed towards the game table surface for data collection. The computer was also positioned on the desk and was used to time experimental trials.

The deck of playing cards was used to determine the outcome of each gamble and contained 51 cards: 2 jokers, 23 sevens, and 26 threes. A payout table was located on the desk near the participant and indicated three winning combination of cards: 3 3-cards equaled 3 tokens, 3 7-cards equaled 7 tokens, and 3 joker-cards equaled 50 tokens (see Figure 1). Because the deck contained 2 jokers, however, 3 jokers was not a possible outcome. This outcome was shown on the payout table in order to mimic payout tables found on many casino games in which one or more high value but low probability outcomes are displayed as a possible response outcome. The programmed PP of the gamble option was 104% (EV = 0.04 tokens).
Experimental design. A repeated-measures design was used to investigate the effects of the number of available response options (one or two) on the number of gambles per session. All participants were randomly assigned to a condition order and experienced each condition only once. Each participant received individual exposure to the conditions during two consecutive 25-min sessions (separated by a 5-min break).

Procedure. After informed consent, demographic information (e.g., age, gender, college major, and ethnic background) was collected from all participants. Prior to the participant entering the experimental room, the experimenter (a) placed 30 tokens in the participant token section of the game table (i.e., the participant’s stake was 30 tokens), (b) arranged the gamble option by placing four face-down cards on the gamble option (see below), and (c) arranged the no-gamble or quit option by placing a face-down card or no card, respectively, on the no-gamble option. The game table is shown in Figure 2. At the start of each session, the experimenter provided a single demonstration of each response alternative. If the first session was the Pass condition, the experimenter read the following instructions:

When you choose this option [the experimenter pointed to the gamble option, which had one card in each of the four rectangles], I will remove one of your tokens and place it on the card in front of the marker. I will then turn over the remaining three cards. If those three cards match any of the combinations on the payout table, you will receive the number of tokens indicated. If you select this option [the experimenter pointed to the no-gamble option, which had a face-down card in the Pass condition or no card in the Quit condition], you will
not lose any of your tokens, but you also will not receive any tokens. Do you have any questions?

For the Quit condition, the last sentence of the previous instruction was changed to:

Anytime you are presented with the marker, you may choose to quit playing the game by selecting this option (the experimenter pointed to the no-gamble option). Doing so will immediately end the session. Do you have any questions?

Following the instructions, the experimenter shuffled the deck of cards and placed one card in each of the four rectangles on the gambling option. The experimenter then started the timer.

Each experimental session consisted of 30 trials. At the beginning of each trial, the experimenter placed the marker in front of the participant. The participant had approximately 3 s to make their choice. If 3 s elapsed and a choice was not made, the experimenter prompted the participant to make a choice. In the Pass condition, participants made choices between a gamble and a no-gamble option. The no-gamble option produced a 45-s timeout (all trials lasted 45-s) followed by the start of the next trial. Note that in this condition, the expected value of the gamble (0.04 tokens) was similar to the value produced by responding on the pass option (0 tokens). In the Quit condition, participants could only chose the gamble option, and were instructed that a single response to the quit option would terminate the session.

The gamble option was the same in both conditions. Each choice of the gamble option cost the participant 1 token and could result in the participant loosing that token or wining 3 or 7 tokens. Participants chose the gamble option by placing the marker on
one of the four squares in front of the four cards on that option. When the gamble option was selected, the experimenter removed one token from participant’s token section of the game table and placed it on the card in front of the marker. The experimenter then turned over the three cards that did not have a token on them and reported the value of each card as it was turned over. If those three cards did not match the winning combinations indicated on the payout table, the participant lost the token that was wagered. Following a loss, the experimenter said, “House wins” and the token was placed in the experimenter’s token section of the game table. If the three cards matched a winning combination, the number of tokens indicated on the payout table were placed in the participant’s token section of the game table (i.e., the net value of a win was the stated value minus one). Following a win, the experimenter said, “Player wins three” or “Player wins seven” (depending on the outcome) and placed the appropriate number of tokens in the participant’s token section of the game table. At the start of each trial, the experimenter placed four new cards on the gamble option. The experimenter shuffled the deck of cards after every five trials. After completing both sessions, participants were debriefed and those who were enrolled in a psychology course offering course credit for research participation received a credit slip. Participants who won the $50 lotteries were contacted via email.

Results

Figure 3 shows the mean number of gambles per session in the Quit and Pass conditions and the error bars show the standard error of the mean (error bars on all of the following figures indicate the standard error of the mean). The results indicate the
mean number of gambles per session was near the maximum number of possible gambles (30 per session) in both the Quit \( (M = 23.35, SD = 9.66) \) and Pass \( (M = 24.85, SD = 6.73) \) conditions. The results of a paired-samples t-test confirmed that the total number of gambles did not differ significantly across the Quit and Pass conditions, \( t(19) = 1.157, p = 0.262 \).

Figure 4 shows the mean percent payback experienced by participants on the gambling option. The percent payback was similar across the Quit \( (M = 99.47\%, SD = 40.07) \) and Pass \( (M = 98.60\%, SD = 42.47) \) conditions. Figure 5 shows the mean number of tokens participants accumulated at the end of a session, which was also similar across the Quit \( (M = 29.85, SD = 9.20) \) and Pass \( (M = 31, SD = 9.97) \) conditions.

Although the overall level of gambling in the Quit and Pass conditions was similar, the pattern of gambling was not. Figure 6 shows the mean consecutive gambles (i.e., the number of gambles that were placed prior to a single quit or pass response) per session in the Quit and Pass conditions (data from the Quit condition are the same as those shown in Figure 3). These data indicate that participants made a single response to the pass option \( (M = 15.40, SD = 12.42) \) much earlier during a session compared to a response to the quit option \( (M = 23.35, SD = 9.66) \), which implies that the pattern of responding during the Pass condition involved interspersed no-gamble responses between strings of gamble responses, a pattern that was not possible in the Quit condition. The results of a paired-samples t-test confirmed that the consecutive gambles was significantly lower in the Pass condition, \( t(19) = 2.944, p = 0.008 \). Together, the data
in Figures 3 and 6 show that providing a pass option influenced participants’ gambling pattern, but not their overall level of gambling compared to a quit option.

To assess possible sequence effects, the data were separated by session and condition order. Figure 7 shows the mean number of gambles in Sessions 1 and 2 for participants in either the Quit-Pass or the Pass-Quit condition order. Figure 7 shows that gambling was similar regardless of whether participants were exposed to the Quit-Pass or Pass-Quit condition sequence. The results of a mixed-model analysis of variance (ANOVA) confirmed there was no effect of session, condition order, or session by condition order interaction on gambling.

Discussion

Experiment 1 examined gambling when participants either did or did not have a pass option available. The results showed that gambling occurred on most trials during both the Quit and Pass conditions. These data suggest that single-option gambling procedures do not generate more gambling than a concurrent gamble no-gamble procedure on which a pass option is concurrently available with gambling. Several features of the procedure may have contributed to this outcome.

First, participants had more opportunities to gamble in the Pass than Quit condition. In the Quit condition, the total number of choices for the gamble option represented the number of consecutive gambles prior to a response on the quit option. In this condition then, the total number of trials completed could vary between 0 and 30. In the Pass condition, the total gambles during a session indicated the number of choices for the gamble option interspersed with choices for the pass option across 30
trials. To make statistical comparisons all data were scaled as total number of choices for the gamble option. However, it is clear that these measures do not necessarily indicate the same type of responding. That is, in the Pass condition, choices for the gamble option include responses that occurred on trials after the non-gambling option was chosen. There were no opportunities to gamble after a quit response in the Quit condition. Plotting data as a proportion of gambles per opportunity does not completely resolve this measurement issue because opportunities were not equivalent across conditions. The number of consecutive gambles prior to the first no-gamble response may therefore provide a better measure of preference for the gambling option. The fewer number of consecutive gambles before a no-gamble response in the Pass condition compared to the Quit condition suggests that the single-option (Quit) tasks may generate greater levels of gambling than multiple-option tasks.

It is uncertain why participants made fewer consecutive gambles before a no-gamble response during the Pass than Quit condition. Possibly, the pass option allowed participants to control their rate of gambling, which may have functioned to reduce their immediate level of risk. In other words, participants' immediate level of risk could be reduced by choosing the pass option in the Pass condition, which did not remove them from the overall gambling situation, whereas, a similar response was not possible in the Quit condition because quitting terminated the session.

Another reason why total number of choices for the gamble option may have been similar across Pass and Quit conditions is that in both conditions participants experienced comparable levels of experimenter demand. As suggested above, a possible
characteristic of single-option procedures is they may inflate participants’ level of gambling as a result of experimental demand for gambling. In the present study, in both the Pass and Quit conditions experimental demand for gambling may have influenced responding because, although participants were given a non-gambling option, neither the pass or quit option may have been viewed by the participant as a desirable response in a study of gambling.

Finally, the similarity in gambling across Pass and Quit conditions may have occurred because neither the pass nor quit option produced tokens. In both conditions, participants could only earn tokens by selecting the gamble option. It is possible that differences in gambling on single-option and gamble no-gamble procedures will occur only when both options deliver tokens for responding.

EXPERIMENT 2

Experiment 1 was designed to compare gambling across conditions in which (a) only a gamble option was available (Quit condition), or (b) a gamble and a no-gamble option were concurrently available (Pass condition). The Pass condition was designed so that the net reinforcement was equal to that in the Quit condition (0 tokens), a condition commonly used in past research. Although this feature made the rates of expected token delivery equal across conditions, it may not have provided a robust test of the effects of including a no-gamble alternative during a gambling session. That is, the contingencies arranged in each of these conditions may have been quite similar in that neither responding on the quit nor pass option delivered tokens. The only notable
difference between the two options was that quitting terminated all gambling opportunities whereas passing terminated only the present gambling opportunity.

It is possible that gambling will occur at high levels whenever it is the only option that produces reinforcers. To test this possibility, Experiment 2 was designed to investigate gambling under a single-option condition and concurrent gamble no-gamble condition when the no-gamble option produced tokens on every response, i.e., a FR 1 schedule.

Several risky choice studies with humans (Pietras, Searcy, Huitema, & Brandt, 2008) and nonhumans (Young, 1981) have shown that when fixed and variable reinforcer amounts are presented concurrently, choice of the variable option is affected by the value of the fixed option. For example, Young (1981) investigated key pecking in pigeons on a concurrent-schedules procedure in which one option produced a certain amount of food and the other produced an uncertain amount. Young found a linear relationship between these values: as the value of the certain amount increased, preference for the uncertain amount decreased. Results of these studies suggest that the effects of the no-gamble option on gambling might vary depending on the magnitude of reinforcement provided by that option.

In Experiment 2, two reinforcer amounts on the token-production option were therefore investigated: 1 token (TP1) and 3 tokens (TP3). This manipulation was designed to assess whether the token magnitude produced on a token-production option influenced responding on the gamble option. Preference for the gamble option was tested across three conditions, TP1, TP3, and Quit conditions. As in Experiment 1, it
was hypothesized that the number of gambles would be greater in the single-option condition (Quit) than in both the concurrent gamble token-production conditions (TP1 and TP3). It was also hypothesized that preference for the gamble option would decrease as the token value of the token-production option in increased, i.e., more gambling would occur in TP1 than TP3 conditions.

Method

Participants. Participants were seven students (7 females) aged 18-21 (M = 19 years). Participants were given identical incentives as participants in Experiment 1.

Setting and apparatus. The setting and apparatus were identical to Experiment 1.

Experimental design. Similar to Experiment 1, a repeated-measures design was used to investigate gambling on a single-option procedure (Quit), which was identical to the single-option condition in Experiment 1 and a concurrent gamble token-production procedure on which the token-production option produced 1 or 3 tokens with certainty (TP1 and TP3, respectively). In all conditions, the gamble option was the same as in Experiment 1. All participants were randomly assigned to a condition order and experienced each condition once. Each participant received individual exposure to conditions during three consecutive 25-min sessions (separated by 5-min breaks).

Procedure. All aspects of the procedures were the same as in Experiment 1 with the following exceptions. First, prior to the participant entering the experimental room, the experimenter arranged the quit or token-production option by placing either a face-down card (Quit), an ace-card (TP1), or a 3-card (TP3) on the no-gamble option. Second,
the instructions were changed to reflect the fact that responses to the token-production
option in the TP1 and TP3 conditions would produce tokens. The new section of the
instructions read:

When you choose this option [the experimenter pointed to the no-gamble
option], you will earn the number of tokens indicated on the card. So, each time
you choose this option I will say “player earns one” [or three] and you will earn 1
[or 3] token.

Results

Figure 8 shows the mean number of gambles per session in the Quit, TP1 and
TP3 conditions. These results indicate that participants tended to place more gambles in
the Quit condition \(M = 26.3, SD = 9.8\), than in either the TP1 \(M = 16.1, SD = 10.98\) or
TP3 \(M = 13.3, SD = 9.38\) conditions. This finding was supported by the results of a one-
way repeated-measures ANOVA, which indicated a significant effect of condition on
gambling, Wilks’ Lambda = 0.204, \(F(2,5) = 9.766, p = 0.019\) (the multivariate results of
this analysis are reported because these data showed significant non-sphericity, \(W =
0.70, p = 0.001; \varepsilon_{H-F} = 0.529\) (see O’Brien & Kaiser, 1985). Bonferroni contrasts on all
pairwise comparisons (based on the critical \(t_{B}(4,6) = 3.521\)) indicated that significantly
more gambles occurred in the Quit condition than in the TP3 condition, \(t_{B} = 4.10\), but no
other pairwise comparisons reached significance. However, a complex Bonferroni
contrast (based on the critical \(t_{B}(4,18) = 2.775\)) between the Quit condition and both the
TP1 and TP3 conditions combined showed that significantly more gambles occurred in
the Quit condition, \(t_{B} = 3.01\).
Figure 9 shows data for each participant. Response patterns in individuals are similar to the means shown in Figure 8, however, the individual data show that the large reduction in responding from Quit to TP1 and TP3 conditions was due primarily to behavior of two participants. For the remaining four participants, the decrease was less marked, and for one participant there was a slight increase in gambling. Overall, six of seven participants showed a decrease in preference for the gambling option under TP conditions.

Figure 10 shows the percent payback experienced by participants on the gambling option. The PP was slightly lower in the Quit ($M = 79.29\%$, $SD = 38.26$) than in the TP1 ($M = 89.57\%$, $SD = 68.83$) and TP3 ($M = 86.0\%$, $SD = 56.52$) conditions and the PP in all conditions was somewhat lower than the programmed value.

Figure 11 shows the mean number of tokens earned on the token-production option and participants’ token total at the end of a session, both of which differed considerably across conditions. The tokens earned on the token-production option increased from the TP1 ($M = 14$, $SD = 11.21$) to TP3 ($M = 49.71$, $SD = 27.43$) condition due to the increase in token magnitude on that option. Similarly, token totals at the end of a session also increased across the Quit ($M = 27.43$, $SD = 4.72$), TP1 ($M = 49$, $SD = 9.24$), and TP3 ($M = 80.71$, $SD = 24.90$) conditions due to the greater number of tokens delivered on the token-production option, as well as the greater number of choices for the no-gamble option.
Discussion

Experiment 1 showed that when a concurrent no-gamble (pass) option was made available on a gambling task, levels of gambling did not differ significantly from conditions in which only a single-option (quit) was available. The present study investigated gambling when the concurrent no-gamble response option also provided reinforcement (a token-production option). Across conditions, the magnitude of reinforcement on the token-production option was manipulated. Unlike Experiment 1, gambling significantly decreased from Quit conditions when the concurrent token-production option was available. There was a slight further decrease in gambling as the magnitude of reinforcement on the token-production option increased from one to three tokens, but the effect was small and did not reach statistical significance.

It was possible that less gambling occurred in TP conditions than in the Quit condition simply because the reinforcement produced on the token-production option ($EV = 1$ or $3$ tokens) was greater than the reinforcement from gambling ($EV = 0$ tokens). It is interesting to note, however, that there was little difference in gambling across TP1 and TP3 conditions despite the threefold difference in $EV$. This suggests that the reduction in gambling from Quit to TP conditions may have occurred not only because the no-gambling option had a greater $EV$ than the gambling option in TP conditions, but also because the TP option provided a no-gambling response alternative. That is, gambling may have decreased across conditions simply because a reinforced, no-gambling option was available.
The presence of the no-gambling option token-production option may have reduced gambling because it reduced experimental demand characteristics. If so, these findings, along with those from Experiment 1, suggest that experimental demands for gambling may be high when only a single gamble option is available or when only the gambling option produces reinforcement. Providing an alternative, token-production option may effectively reduce experimenter demand.

That gambling was not significantly affected by the magnitude of reinforcement on the token-production option contrasts with previous risky-choice research (e.g., Young, 1981). For two participants, the lack of difference between the two TP conditions likely was due to a floor effect: gambling in the TP1 condition was already at near-zero levels. For the remaining participants, gambling decreased across conditions, but only slightly. Possibly, gambling would have decreased further with a more extended exposure to the task.

EXPERIMENT 3

The use of a participant stake prior to gambling sessions has been commonplace in studies on decision-making and gambling (e.g. Lichtenstein, 1965; Preston & Barrata, 1948; Schreiber & Dixon, 2001). In studies in which losses are possible, participants are typically staked with tokens that are later exchangeable for some commodity (usually money), although in some studies participants are staked with valueless tokens (see Weatherly & Phelps, 2006). Concerns have been raised about the effects of the participant stake because, as discussed above, studies on decision-making have found that choices tend to be more risk prone when participants were staked with the
experimenters’ money compared to when they gambled with their own money (Ladouceur et al., 1991; Thaler & Johnson, 1990). If it is assumed that people will generally show less risk taking as the reinforcing value of the wagered commodity increases, these findings suggest that the source of the stake may be a motivating operation affecting the reinforcing value of the wagered commodity (Laraway, Syncerski, Michael, & Poling, 2003; Michael, 1982).

Still other studies have found that procedural aspects of the participant stake also influences risk taking, even when the experimenter provides the commodity. Weatherly et al. (2006) conducted a study in which participants gambled on a simulated slot machine with points exchangeable for money following their participation. In first experiment, gambling was studied under three conditions in which participants were given different instructions. The first condition modeled typical participant-stake procedures. Participants were told that once the session began they would have 100 points that were worth $10 ($0.10 each) with which they could gamble. In two other conditions, participants were instructed that the experimenter was giving them $10 with which they could buy tokens that could be gambled during the session. In one of these conditions, the experimenter held a $10 bill while reading the instructions and in the other, the participant was allowed to hold the bill during the instructions. Gambling in this last condition perhaps best resembles conditions found in real-world gambling. Gambling was significantly lower than in this third condition. These findings suggested that risk taking varied systematically with the procedures used to provide participants a
commodity with which to gamble. As the value of the commodity increased, risk taking decreased.

Research in which participants gamble their own money may be the most valid model of real-world gambling. However, the ethical and legal concerns with allowing participants to lose their own money during participation makes this approach unsuitable for most researchers (see Weatherly et al., 2006). An alternative to letting participants gamble with their own money is to allow participants to gamble with money they have earned during a session. Many studies have shown that losing money that was earned during an experiment serves an aversive stimulus function (e.g., Pietras, Brandt, & Searcy, 2010). Therefore, an alternative to staking participants with tokens may be to require the participants to earn tokens within a session. As mentioned above, one advantage of the gamble token-production procedure is that it makes an initial participant stake unnecessary because tokens can be earned within a gambling session by choosing the no-gamble option.

Experiment 3 aimed to compare gambling when tokens were staked prior to a session to gambling when tokens were earned via the token-production option during a session. Two Participant Stake conditions were investigated. In the Stake condition, participants received tokens prior to each session (this condition modeled the typical participant-stake procedure used in past experiments) and in the Earn condition, they did not receive tokens prior to the session and were required to earn tokens during each session. It was hypothesized that preference for the gamble option (i.e., risk taking) would be greater in the Stake than in the Earn condition.
In Experiment 2, there was little difference in gambling as the value of the token-production schedule was manipulated from one to three tokens. A second aim of Experiment 3 was to further explore the effects on gambling of the magnitude of reinforcement on the token-production option varied. Thus, two token-production conditions, TP1 and TP3, were investigated to test the reliability of findings of Experiment 2 findings. The effects were tested between, rather than within groups of participants.

**Method**

*Participants.* Participants were 29 students (14 females, 15 males) aged 18-22 (M = 18.8 years). Participants were given identical incentives as participants in Experiment 1.

*Setting and apparatus.* The setting and apparatus was identical to Experiment 1.

*Experimental design.* A 2 (Participant Stake) X 2 (Token Production) mixed-model design was used to investigate the within-subject effects of Participant Stake (Earn and Stake) and the between-subjects effects of token production (TP) magnitude (TP1 or TP3) on preference for the gamble option. Participants were randomly assigned to one TP condition and to one Participant Stake condition order. Participants received individual exposure to one TP condition and to each Participant Stake condition across two consecutive 25-min sessions (separated by a 5-min break).

*Procedure.* In all conditions, participants were given a choice between a gamble and a token-production option. All aspects of the procedures were identical to TP1 and TP3 conditions in Experiment 2, with the following exceptions. First, participants were
given a single demonstration of each response option and were read the following instructions prior to the first session:

For this task, you will be repeatedly choosing between two options. One option will produce the same number of tokens each time you choose it. The other option can produce 3, 7, or 50 tokens, but can also result in the loss of a token. Choosing this option (the experimenter pointed to the no-gamble option) will always produce the number of tokens indicated on the card. You may choose this option on any trial. When you choose this option (the experimenter pointed to the gamble option), I will remove one of your tokens and place it on the card in front of the marker. I will then turn over the remaining three cards. If those three cards match any of the combinations on the payout table, you will receive the number of tokens indicated. Do you have any questions?

Second, participants were given no tokens prior to Earn sessions. Because participants were required to have at least one token in order to select the gamble option, participants’ first response was always to the token-production option during Earn sessions. Following this forced response, Earn sessions consisted of 30 choice trials. However, during these 30 trials, it was possible that participants could have zero tokens on any given trial (because of losses experienced on the gamble option) and in these situations, the participant was again required to select the token-production option. Because these were forced-choice trials, they were not included in any performance measures reported below. The main dependent measure, then, was the number of choices for the gambling option per opportunity. As in Experiment 2, participants were
given 30 tokens prior to Stake sessions and those sessions always consisted of 30 free-choice trials.

Results

Figure 12 shows the mean proportion of choices for the gamble option per choice opportunity across the TP and Participant Stake conditions. The horizontal dashed line at .5 indicates the indifference point, or the point at which both options were equally preferred. This figure indicates that participants' preference for the gamble option in the TP1-Earn ($M = 0.307, SD = 0.165$) condition was slightly more risk averse than preference in the TP1-Stake ($M = 0.435, SD = 0.257$), TP3-Earn ($M = 0.478, SD = 0.285$), and TP3-Stake ($M = 0.500, SD = 0.336$) conditions. The results of a Participant Stake (Stake and Earn) by TP (TP1 and TP3) mixed-model ANOVA indicated no significant main effect of Participant Stake, $F(1,27) = 2.164, p = 0.153$, Token Production, $F(1,27) = 1.860, p = 0.184$, or Participant Stake by Token Production interaction, $F(1,27) = 1.089, p = 0.306$, on preference for the gamble option.

Figure 13 shows the mean experienced percent payback on the gamble option. Mean $PP$ was somewhat lower in the Stake (TP1-Stake $M = 72.09\%, SD = 45.90$; TP3-Stake $M = 75.57\%, SD = 72.43$) than in the Earn (TP1-Earn $M = 95.13\%, SD = 75.51$; TP3-Earn $M = 88.40\%, SD = 59.88$) conditions. Figure 14 shows the mean number of tokens earned on the token-production option and participants' token total at the end of a session. As expected, there was a similar pattern between TP1 and TP3 conditions, as was seen in Experiment 2. That is, accumulated tokens increased with increased TP
values. Similarly, the amounts of accumulated tokens were greater in Stake compared to Earn conditions as a result of the 30 token stake.

To test for possible sequence effects, the data were organized by session and Participant Stake condition order. Data from both TP 1 and 3 groups were combined (participants received the same TP value during both sessions). Figure 15 shows for all participants the mean proportion of gambles per choice opportunity across Sessions 1 and 2 for those participants receiving Earn-Stake or Stake-Earn condition orders and the horizontal dashed line indicates the indifference point. This figure shows that preference for the gamble option was lower in participants given the Earn-Stake condition order, compared to participants given the Stake-Earn condition order, and that preference for the gamble option was lower in Session 2 than Session 1. For participants in the Stake-Earn condition order, preference for the gamble option was not only much greater in Session 1 ($M = 0.636$, $SD = 0.278$) than Session 2 ($M = 0.436$, $SD = 0.292$) but was also much greater than preference for the gamble option among participants in the Earn-Stake condition order in both Sessions 1 ($M = 0.352$, $SD = 0.188$) and Session 2 ($M = 0.290$, $SD = 0.201$). A session (Session 1 and Session 2) by condition order (Earn-Stake and Stake-Earn) mixed-model ANOVA indicated a significant effect of session, $F(1,27) = 8.320$, $p = 0.008$, and condition order, $F(1,27) = 7.352$, $p = 0.012$, on preference for the gamble option. The session by condition order interaction was not significant, $F(1,27) = 2.280$, $p = 0.143$. Bonferroni contrasts on all pairwise comparisons (based on the most conservative estimate of the critical $t_{6}(6,13) = 3.107$) indicated that preference for the gamble option in Session 1 for participants in the Stake-Earn
condition order was significantly greater than their preference in Session 2, $t_B = 3.16$, and greater than preference in participants in the Earn-Stake condition order during both Session 1, $t_B = 4.40$, and Session 2, $t_B = 5.37$. All other contrasts were nonsignificant.

One problem in interpreting the interaction effect is that the ANOVA and post-hoc analyses on Session lead to contradictory findings. The problem stems from the finding that preference from Session 1 to Session 2 significantly decreased for the Stake-Earn condition order, but not for the Earn-Stake condition order. This implies an interaction between these variables, but the interaction in the ANOVA was not significant. To show these patterns more clearly, Figure 16 shows for each participant the proportion of gambles per choice opportunity across Sessions 1 and 2 in the Earn-Stake and Stake-Earn condition orders, collapsed across TP value. The horizontal dashed line indicates the indifference point. The results indicate that for most participants' preference for the gamble option was consistently lower in the second session than the first for both condition orders, however, the change in preference tended to be much greater for participants in the Stake-Earn condition order.

Discussion

The present study was designed to investigate the effects of the participant stake and TP value on gambling in a concurrent gamble token-production procedure. There were no main effects of stake or TP value. A test on the effects of experience (session by condition order analysis) on gambling, however, revealed a significantly higher preference for the gamble option in participants who experienced stake
conditions in Session 1 (Stake-Earn), as compared to preference in the same participants during Session 2, and preference in both sessions in participants who experienced the Earn-Stake condition. In other words, participants that received a stake during their initial exposure to the gambling procedure showed risk proneness whereas risk aversion was observed in all participants during all other conditions. This finding provides some evidence that staking participants prior to experimental sessions may increase risk taking.

It is uncertain, however, why gambling was low in the Stake condition for participants who experienced the Earn-Stake condition order. One possible explanation is that preference may become risk averse with repeated experience on the procedure. This possibility is supported by the significant main effect of session on preference. That gambling decreased with experience is consistent with the results of a prior study that also showed a decrease in gambling on a gambling simulation across repeated exposures to gambling conditions, albeit the decrease occurred over a much longer exposure (see Brandt & Pietras, 2008). Experiment 2 also showed a decrease in gambling across sessions, but the effect was most apparent from Session 2 to 3.

Overall, the finding that gambling was higher in Stake conditions for participants who experienced Stake conditions in Session 1 is consistent with results of prior studies showing that gambling is more likely when participants gamble with staked money than their own money. The results therefore provide some additional evidence that gambling procedures that stake participants with money may obtain higher levels of gambling than procedures that allow participants to gamble with their own money.
EXPERIMENT 4

Experiments 2 and 3 investigated the effects on gambling of the magnitude of reinforcement on the token-production option and found little difference across two magnitude conditions (1 vs. 3 tokens). This finding contrasts with the results of previous studies that have shown that preference for an uncertain option varies with the magnitude of reinforcement programmed on the certain option (e.g., Young, 1981). The results were also inconsistent with predictions based on expected value. Experiment 4 was therefore designed to further explore the effects on gambling of the magnitude of reinforcement on the certain option.

In Experiment 2, there was a slight decrease in gambling as the magnitude of reinforcement on the no-gamble (token production) option increased, but the effect was not significant. In Experiment 3, the effect of reinforcer magnitude may have been obscured by the stake manipulations. Experiment 4 investigated the effects on gambling of the reinforcer magnitude of the certain option when participants had to earn tokens during a session. Gambling was investigated under three TP values (TP1, TP 2, and TP3) using a within-subject design. The TP1 and TP3 conditions therefore systematically replicated conditions of Experiments 2 and 3. All conditions in Experiment 4 were similar to the Earn condition in Experiment 3. It was hypothesized that preference for the gamble option would decrease as the token-production value increased.
Method

Participants. Participants were 18 students (15 females, 3 males) aged 18-21 ($M = 18.6$ years). Participants were given identical incentives as participants in Experiment 1.

Setting and apparatus. The setting and apparatus were identical to Experiment 1.

Experimental design. A within-subjects design was used to investigate the effects of the Token Production (TP1, TP2, and TP3) on preference for the gambling option. Participants received individual exposure to each TP condition once during three consecutive 45-min sessions (separated by a 5-min break). Condition order was randomized across participants.

Procedure. All aspects of the procedures were identical to Experiment 3 Earn conditions with the following exceptions. First, prior to the participant entering the experimental room, the experimenter arranged the token production option by placing an ace-card (TP1), a 2-card (TP2), or a 3-card (TP3) on the no-gamble option. Second, all sessions consisted of 51 trials instead of 31 trials. Participants did not receive tokens prior to any session. Therefore, all sessions required a single response to the token-production option on the first trial and on any subsequent trial in which the participant had zero tokens (data from these trials were omitted when calculating preference for the gamble option).
Results

Figure 17 shows the mean proportion of choices for the gamble option per choice opportunity across all TP conditions and the horizontal dashed line indicates the indifference point. This figure indicates that choice for the gamble option in the TP1 ($M = 0.490$, $SD = 0.256$) and TP2 ($M = 0.475$, $SD = 0.295$) conditions was near indifferent, but that choice was slightly risk averse in TP3 ($M = 0.386$, $SD = 0.251$). The results of a one-way repeated-measures ANOVA showed no significant effect of TP value on preference for the gamble option, $F(2,34) = 2.038$, $p = 0.146$. Condition order effects were not tested due to limited data for each possible condition sequence.

Figure 18 shows each participant's preference for the gamble option across TP conditions. This figure shows that there were substantial individual differences in risk sensitivity, but generally supports the averaged results shown in Figure 17. That is, this figure shows that the riskiest responding (preferences near 1) tended to occur in the TP1 and TP2 conditions whereas the most risk averse responding (preferences near 0) tended to occur in the TP2 and TP3 conditions.

Figure 19 shows the mean experienced percent payback, which was near the programmed level of 104% in the TP1 condition ($M = 108.36\%$, $SD = 64.13$), however, it was considerably lower in the TP2 ($M = 75.38\%$, $SD = 29.53$) and TP3 ($M = 75.11\%$, $SD = 49.60$) conditions.

Figure 20 shows the mean number of tokens earned on the token-production option and participants' token total at the end of a session. As expected, accumulated tokens increased with increased TP values.
Figure 21 shows the mean proportion of choices for the gamble option per choice opportunity across sessions collapsed across TP value. This figure indicates that preference was near indifferent in Session 1 ($M = 0.51$, $SD = 0.26$), but was slightly risk averse in Session 2 ($M = 0.43$, $SD = 0.25$) and Session 3 ($M = 0.41$, $SD = 0.29$). Although gambling appeared to decrease slightly across sessions, particularly form Session 1 to 2, the results of a one-way repeated-measures ANOVA revealed that gambling did not differ significantly across sessions, $F(2,34) = 1.711$, $p = 0.196$.

Discussion

Experiment 4 investigated the effects of TP value on gambling using a concurrent gamble token-production procedure. As predicted, preference for the gambling option tended to decrease slightly as the reinforcer value of the token-production option increased, however, the effects were not statistically significant. In general, participants showed risk indifference or risk aversion across all conditions.

That responding tended to be more risk averse than risk prone is consistent with previous studies, which have generally shown greater preference for fixed reinforcement amounts compared to variable amounts (see O’Daly, Case, & Fantino, 2006; Pietras & Hackenberg, 2001). However, in most previous studies preference was assessed among fixed and variable amounts with similar means. Thus, the finding that very few participants exclusively chose the token production option in any condition is somewhat surprising because the mean reinforcement amount was much greater on token-production option than on the gamble option.
Finally, that preference tended to be slightly risk averse across TP conditions was consistent with responding in Experiments 2 and 3. Across each of these experiments, however, very few participants showed exclusive preference for the token-production option, even when choices for this option produced tokens at a far greater rate (e.g., TP3) than choosing the gamble option. Among other possible explanations for this finding, discussed in more detail below, is that increased token accumulation experienced during higher TP conditions may have inadvertently increased risk proneness.

GENERAL DISCUSSION

Overview

Research on behavior in situations involving uncertainty and risk have shown that behavior is sensitive to reinforcer probability (see Kahneman & Tversky, 1984; Mazur, 1989), as well as to variability in reinforcer delay (see Mazur, 1991), and magnitude (see Bonem & Crossman, 1988; Barnard & Brown, 1985; Kohn, Kohn, & Staddon, 1992). Because most research on risk preferences was not designed to study gambling per se, the contingencies that were programmed on these experimental tasks often differed considerably from those found in real-world games of chance. Few studies have systematically investigated how procedural variables affect risk sensitivity, however, research on choice under uncertainty has shown that the use of real as opposed to hypothetical outcomes (Slovic, 1969a; Weber, et al., 2004), the nature of the commodity wagered (Ladouceur et al., 1991; Thaler & Johnson, 1990; Weatherly et al., 2006; Weber & Zuchel, 2005), the variability of the outcomes produced (see O'Daly et
al., 2006), the number of response options are available (see Catania, 1963), and the amount of experience with the available options (see Barron & Erev, 2003; Gärling & Romanus, 1997; Hertwig, et al. 2004; Keren & Wagenaar, 1987; Lopes, 1981; Weber, et al., 2004; Wedell & Böckenholt, 1990) all influence risk preferences.

Recently, operant psychologists have developed simulated-gambling procedures designed to mimic many important characteristics of real-world games of chance (Dixon et al., 2006; Haw, 2008; MacLin et al. 2007; Weatherly et al., 2006; Weatherly & Phelps, 2006). For instance, participants are typically given repeated experience with multi-outcome gambles and participants wager real commodities. Although these experimental tasks might better simulate games of chance, important differences remain. For example, the gambling simulations typically provide limited response options and rely on participant stake procedures. One goal of the present research was to investigate whether these procedural variables affect gambling.

In the present research, gambling under standard simulated-gambling conditions was compared to gambling under conditions that were designed to better approximate real-world gambling contingencies. Under standard conditions, gambling was measured when a gamble was the only available response option and a stake was given to participants. In other conditions, gambling was measured when participants could choose between a gamble option and a no-gamble option that produced tokens (reinforcers) and participants were required to earn tokens to gamble with (i.e., participants were not provided with a stake). Overall, the findings showed that risk taking tended to be greatest under standard procedures.
Single- and Concurrent-Option Procedures

Experiments 1 and 2 investigated whether the availability of an alternative, no-gamble option influenced levels of gambling. In standard laboratory gambling procedures, participants can either gamble or quit the session. In real-world games of chance, a gambler can intersperse non-gambling responses with gambling without permanently removing themselves from the gambling environment (see Dixon et al., 2006). In Experiment 1, gambling was investigated when only one response option was available (participants could either gamble or quit the session), and when two response options were available (participants could either gamble on a trial or pass and progress to the next trial). Levels of gambling were similar across conditions, but participants tended to make a non-gambling response sooner when they could choose a pass option. In Experiment 2, gambling was compared across conditions when (a) only the gambling response option was available, and (b) a gambling and a no-gamble token production option were concurrently available. Responding on the no-gamble option produced tokens with certainty. The amount of tokens produced by the no-gamble option varied across conditions and was either 1 or 3. Experiment 2 showed that gambling levels were lower in the two-option conditions, but that there were little differences across the two token-value conditions. The results of Experiments 1 and 2 suggest that multiple-option conditions produce lower levels of gambling than single-option conditions, but that the difference in gambling is greatest when the no-gamble option also produces reinforcement.
It is possible that gambling was lower in Experiment 2 when a second option was available not because the no-gamble option produced reinforcement with certainty but because the no-gamble option produced a higher expected value than the gamble option. Only in Experiment 1 was the EV similar across the two options (the gambling option EV = 0.04 tokens and a pass no reinforcement, EV = 0 tokens). In Experiment 2, the EV on the no-gamble option was 1 or 3 and was therefore much higher than that produced on the no-gamble option. Participants may have gambled less during the concurrent-conditions because choosing the no-gamble option maximized reinforcement. Such a finding is consistent with the results of many studies that have shown that EV can influence risky choice (see Karen & Wagenaar, 1987). To further explore this possibility, additional studies could investigate gambling when the EV of the gamble option was increased to match the EV of the token-production option. Such a manipulation would better separate the effects on preference of reinforcer variability and EV. Increasing the EV of the gamble much over 0 tokens, however, would make the gamble unlike most real-world games of chance. It is interesting to note that preference for the token-production option did not significantly increase as the EV of this option increased. This suggests that EV alone may not be responsible for the lower levels of gambling under concurrent conditions.

That gambling differed across single- and multiple-option conditions in Experiment 2 is in accord with prior gambling research showing that the effects of environmental variables on gambling differ depending on whether a single or concurrent procedure is used. For instance, both Brandt and Pietras (2008) and Dixon et
al. (2006) investigated the effects of win frequency and size on gambling using a single or concurrent slot-machine simulation, respectively. In both studies, it was predicted that participants would prefer options delivering small frequent wins over options that delivered infrequent but larger wins. Brandt and Pietras, who used the single-option procedure, found that rates of gambling in only one of three participants were higher in the small frequent win condition than in the large, infrequent win condition. Alternatively, using a concurrent-gambles procedure, Dixon et al. found a reliable preference for the slot machine that produced small, frequent wins over the slot machine that produced large, infrequent wins. Such findings suggest that single-option procedures do not provide as sensitive of a measure of the effects of win frequency and size on behavior as concurrent procedures.

Similarly, single and concurrent slot-machine simulations have been used to investigate whether behavior is sensitivity to changes in the PP of gambles. Several studies (Brandt & Pietras, 2008; Schreiber & Dixon, 2001; Weatherly & Brandt, 2004) using a single slot-machine simulation have showed that gambling does not vary systematically across a range of PP values. However, a recent study by Haw (2008) showed that when participants were given a choice between slot machines that differed in PP, some participants showed a preference for the slot machine that produced the highest PP. Because prior research with humans has shown that subjects typically prefer an option when it has a greater EV relative to other options and when repeated choices can be made (Karen & Wagenaar, 1987), these findings suggest that single-option procedures also do not provide an adequate measure of sensitivity to PP.
As these two examples illustrate, the concurrent gambles procedure appears to provide a better test of sensitivity of gambling to environmental variables (a similar pattern has emerged among investigations of reinforcement magnitude, see Bonem & Crossman, 1988). The present research, however, is the first study to directly compare gambling levels across conditions that provide only a single response option to conditions that provide concurrent response options. It is important to note however, that unlike prior studies, in the present research a concurrent gamble no-gamble procedure was used rather than a concurrent-gambles procedure. Whether a similar pattern will be found if variables such as win size and rate or PP were manipulated within the concurrent gamble no-gamble procedure therefore remains to be investigated.

As discussed above, one possibility for the different patterns of responding across single and concurrent procedures shown in Experiment 2 is that the concurrent no-gamble option reduced the experimental demands for gambling. However, even under concurrent conditions gambling occurred at non-zero levels. It is possible, then, that experimenter demand still affected performance. Although a non-gambling option was available, participants were told in the instructions that they would be presented with a gambling option. If in fact participants behavior was influenced by the knowledge that they were participating in a gambling study, greater risk taking would be the expected performance (see Navarick, 2007). Future studies could compare gambling in participants when they were or were not given instructions containing the world
gambling. Such studies could provide additional information about the role of demand on gambling in the concurrent task.

Although the type of options programmed on the concurrent gamble no-gamble procedure were designed to better approximate gambling under naturalistic conditions, the present experiments were not designed to directly test the ecological validity of the results. Therefore, it remains uncertain how well the procedure actually models real-world gambling. To address this research question directly, comparisons of gambling under laboratory conditions and in real gambling environments would be needed. Such comparisons are difficult to conduct, however, given the practical difficulties and ethical issues involved in studying gambling outside the laboratory. In fact, only a few studies have attempted such comparisons (Andreson & Brown, 1984; Dickerson, 1979; Ladouceur et al., 1991) and none of those studies were conducted in the U.S.

The no-gamble option arranged in the present study yielded the same reinforcer as the gamble option: generalized conditioned reinforcers or tokens. Arranging two options that produced tokens may simulate choices between working for money and gambling for money, but it does not closely model choice options available in a casino. In a casino, non-gambling behaviors are more likely to consist of activities such as social interaction, observing others, eating, drinking, or smoking. These activities do not necessarily produce reinforcement on a predictable schedule and the reinforcers are very different from those produced by games of chance. Analyzing the effects on gambling of the availability of other types of reinforcers may therefore be a fruitful area of future research. For example, identifying reinforcers that effectively compete with
reinforcers provided by gambling (e.g., social reinforcers) may lead to the development of new methods for reducing gambling. On the other hand, some reinforcers may function as complementary reinforcers that may increase the reinforcing value of gambling. For instance, nicotine appears to produce greater discounting of delayed outcomes (Bickel, Odum, & Madden, 1999), which may reduce participants' risk-sensitivity during a gambling procedure (Rachlin, 1990).

Finally, the concurrent gamble no-gamble task may be improved upon by adding another gamble option. Such a procedure would be designed as a three-option task in which one option was a token-production option, and the second and third options were both gambles. This procedure would have the same benefits as the gamble no-gamble procedure, that is, it would eliminate the need for a participant stake and eliminate the requirement to gamble (i.e., reduce possible experimental demands for gambling), and it would allow preference to be assessed between concurrent gamble options within a single session. As indicated above, arranging concurrent-gamble options appeared to generate gambling sensitivity to certain environmental variables (e.g., percentage payback and win probability and size) whereas a similar sensitivity was not produced on a single-option procedure investigating the same variables.

**Staked and Earned Commodities**

During laboratory experiments on gambling, participants must possess some commodity in order to wager, thus, a participant-stake procedure is typically used. Studies have shown, however, that the magnitude of the stake (Weatherly & Brandt, 2004), its source (Ladouceur et al., 1991; Thaler & Johnson, 1990), and procedures used
deliver a participant (Weatherly et al., 2006) influence risk taking. In each case, risk-taking was lowest when the conditions most closely mimicked those found in real-world gambling. This suggests that standard-laboratory participant-stake procedures may generate artificially high levels of risk-taking.

Experiment 3 was therefore designed to investigate gambling when participants were or were not given a stake. One goal of this procedure was to determine whether the concurrent-gamble no gamble procedure could eliminate the need for using a stake. In the Stake condition, participants received tokens exchangeable for entries into a $50 lottery prior to sessions. In the Earn conditions, participants started each session with zero tokens, but tokens could be earned with certainty during the session by selecting the token-production option (tokens could also be earned probabilistically on the gamble option). Experiment 3 showed that preference for the gamble option was greater in the Stake than Earn conditions, but only when the Stake condition was experienced first. That gambling was initially high with tokens staked prior to the session suggests that those tokens were less valuable to the participant than tokens obtained during later conditions in which they had to be earned first. This possibility is consistent with studies showing that increasing the value of money reduces gambling (see Weatherly & Brandt, 2004). In addition, it is consistent with studies with humans (e.g., Alessandri, Darcheville, Delevoye-Turrel, & Zentall, 2008) and nonhumans (Clements, Feltus, Kaiser, & Zentall, 2000) that have shown the work ethic effect, or the finding that stimuli which required more work to produced may be more reinforcing than stimuli that were easy to produce.
It is uncertain whether a procedure, which requires participants to earn tokens to gamble, has greater ecological validity than one that stakes participants with tokens. However, it is noteworthy that one of the few studies in which the ecological validity of laboratory-gambling procedures was investigated (Ladouceur et al., 1991) found that gambling levels were lower when participants risked their own money in a naturalistic setting than when money was provided by the experimenter during similar conditions in a laboratory setting. That gambling was greater in the laboratory when money was staked is comparable to the findings of the present research. The present studies, together with Ladouceur et al. (1991), therefore suggest that money earned during a gambling session may be as valuable to participants as money acquired prior to participation. This possibility suggests experimental gambling tasks that use participant stakes may generate high levels of risk taking and that procedures in which participants must earn tokens during a session may reduce this problem, which makes it more similar to the gambling conditions found in the natural environment. In other words, when gambling with earned tokens rather than staked tokens is arranged in the laboratory, the results may have more ecological validity.

Token-Production Schedule

As discussed above, one goal of the present research was to investigate gambling when an alternative, no-gamble option was available. It was assumed that the reinforcer magnitude on the no-gamble option would affect gambling, but the extent to which it would affect gambling was unknown. Therefore, in Experiments 2, 3, and 4, gambling was investigated across several magnitudes of reinforcement on the no-
gamble option. In Experiments 2 and 3 gambling was investigated when the no-gamble option produced one or three tokens (under stake or earn conditions), and in Experiment 4 gambling was investigated when the no-gamble option produced, one, two, or three tokens (under earn conditions).

In Experiments 2 and 4, higher token magnitudes on the token-production option were associated with lower levels of gambling. However, in both cases, considerable individual differences were observed and the effects failed to reach statistical significance. When tested between independent groups of participants in Experiment 3, again, no significant relationship between token magnitude and gambling was found, and in fact, preference for the gamble option tended to be slightly greater in the larger token-magnitude condition. Together, these experiments failed to show reliable effects on gambling of the token magnitude produced on the token-production option.

One possible explanation for the insensitivity to reinforcer magnitude shown in these experiments is that performance was strongly controlled by instructions. Participants were given extensive instructions (and responses were modeled by the experimenter) because the task was novel. The extensive instructions, however, may have reduced the sensitivity of behavior to the reinforcer magnitude. This possibility is supported by previous research that has shown that behavior in human participants was more sensitive to changes in reinforcement parameters when performance was uninstructed versus instructed (see Dixon & Hayes, 1998; Kudadjie-Gyamfi & Rachlin, 2002; Catania, Matthews, & Shimoff, 1982).
Another possible explanation for insensitivity to reinforcer magnitude on the certain option was that changes in token-production magnitude affected participants’ rate of token accumulation (see Figures 11, 14, and 20). That is, as the token magnitude increased so did the number of accumulated tokens. Some studies with humans (e.g., Pietras & Hackenberg, 2001) and nonhumans (e.g., Barnard & Brown, 1985) have shown that risk aversion increased as reserves increased (in the present studies, reserves are analogous to accumulated tokens). However, this type of pattern has generally been found when participants were motivated to keep reserves above a minimum level. Because no explicit minimum requirements were present in the current studies, the increasing token reserves may have actually had the opposite effect on gambling: greater reserves may have led to greater risk-taking. This possibility is supported by Silberberg, Murray, Christensen, and Asano (1988), who showed that participants were riskier during 10 trials of roulette play when staked with $10,000 compared to when staked with $10 (hypothetical amounts). Although increased token-production magnitude was hypothesized to reduce risk taking, the possible risk increasing effects of increased reserves may have been present across conditions of increased token production. If so, the effects of these variables across token-production would have affected risk in opposite directions therefore confounding the intended analysis.

Additional analyses provide further evidence that gambling may have been influenced by accumulated tokens. A participant’s tokens were always arranged in stacks of ten tokens and as tokens were gained and lost, they were added and removed from the stack of the most recently earned tokens, i.e., the last stack. Although it was
clear across the experiments that responding did not tend to vary with the total number of accumulated tokens, casual observation suggested that gambling was more likely when the last stack was incomplete (1-9 tokens) compared to when it was complete (10 tokens), in other words, gambling appeared to be less likely when a wager made the last stack change from complete to incomplete. To examine this possibility more systematically, trial-by-trial analyses were conducted on participants' choices in Experiment 4 to determine the probability of a gamble response in the presence of each last-stack value (1-10) for all participants. Data were examined in Experiment 4 because only magnitude was manipulated in that experiment. Both visual and inferential statistical analyses of these data indicated a significant shift in responding as a function of token stack: choice was more risk averse when the last stack was complete ($M = 0.34, SD = 0.29$) than when it was incomplete ($M = 0.45, SD = 0.26$) (see Figure 22).

It is unclear why the number of accumulated tokens in a stack influenced gambling. Because the outcomes of the gamble were random, certain stack values should not have been associated with any particular outcome, thus it is unlikely that this value served a discriminative function. A more likely possibility is that this value occasioned verbal responses that influenced gambling. Prior studies have shown, for example, that participants self-reported gambling strategies are often related to token reserves, or the number of accumulated tokens (see Brandt & Pietras, 2008). Brandt and Pietras had participants play a computerized single-option slot-machine simulation with points exchangeable for money across many sessions. They showed that gambling in 4 of 6 participants appeared to be influenced by their self-generated gambling strategies.
This conclusion was based on self-reported records of the participants’ strategies collected at the end of the experiment as well as from performance on the gamble task. The findings suggested that sometime during their participation, participants established an *earnings target*, or a minimum number of points with which they would be willing to end a session. For instance, participants always started a session with 50 points and in one participant, the reported earnings target was 40 points. Across 39 sessions, only twice did this participant end a session with fewer than 40 points. In the current study, participants had actual tokens (i.e., poker chips) stacked in front of them rather than points on a computer monitor, however, the change in risk from complete to incomplete stack values may have been affected by a self-generated rule similar to the earnings targets reported in Brandt and Pietras. Thus, it appears from the last-stack analysis that even seemingly innocuous procedural variables, such as how the tokens are arranged for participants, may actually alter within session sensitivity to risk and therefore may be important for understanding risk sensitivity.

It is also interesting to note that across all studies, gambling occurred more often than would have been expected given the EV of the gamble and token-production options. Previous studies have generally shown that participants prefer certain gains to probabilistic gains with similar or even greater average means (see Kahneman & Tversky, 1979). However, the gamble option in the present studies had a far lower mean return than the certain gain. The gamble option $EV = 0.04$ tokens, thus wagering on this option produced minimal reinforcement on average (just slightly more than breaking even). Responses on the token-production option, however, generated tokens with
certainty, thus the EV of this option was equal to the number of tokens produced. The 
EV of the token-production option was therefore always greater than the EV of the 
gamble option. It was possible for the obtained EV to differ from the programmed EV, 
however, the mean experienced EV did not exceed zero in most TP conditions (see 
Figures 10, 13, and 19). Despite this, in many cases participants gambled on over half of 
the trials. The amount of risk-taking in these studies was relatively high considering the 
low EV of the gamble. Thus, it is possible that there was little effect on gambling of the 
magnitude of reinforcement on the certain option because choice was strongly risk 
prone.

To the experimenter’s knowledge, no prior study has shown such strong risk 
proneness when participants were given a choice between a certain gain and risky 
option with zero expected value. One variable that may have generated the high levels 
of risk taking is that participants were told that a very large win (i.e., three jokers) was 
possible. Participants were instructed that a large win was possible because it was 
assumed that very little gambling would occur if a certain token-production option was 
concurrently available. Providing instructions to participants that a very large win was 
possible (although in actuality it was not), however, made the gamble option appear 
more valuable than it actually was. Future studies could investigate the effects of the 
presence of such a large win on gambling (for a discussion on the effects of large wins 
that are actually delivered, see, Kassinove & Schare, 2001).

Finally, it may have been possible that greater sensitivity to the EV among the 
options would have been observed given greater experience with the gambling
procedure, that is, gambling may have decreased further given greater experience with the discrepant EVs between the token-production and gamble options. Evidence from past studies indicated that strong risk aversion to a gamble with a negative average EV was only observed following considerable experience, often several hours, with the procedure (Brandt & Pietras, 2008). Although the programmed EV of the gamble option in the present study was 0.04, the mean experienced EV tended to be less than zero, therefore, similarly high levels of experience may have been necessary to generate strong risk aversion in the present studies.

Summary

Common laboratory-gambling simulations have features that may generate higher levels of risk taking than would occur under settings that are more naturalistic. Specifically, gambling simulations commonly provide participants with only a single reinforced response option and arrange for participants to gamble with experimenter-provided money. The present research investigated whether these methodological features influenced gambling and found that gambling levels were higher when a single-reinforced option was present compared to when multiple options were present, and that gambling levels were higher when participants gambled with staked money compared to earned money, although the effects in the latter case were dependent on condition sequence. The results suggested that a concurrent gamble token-production procedure that arranges multiple response options and that arranges for participants to gamble with earned money may provide a better laboratory-gambling simulation than existing procedures. Overall, this research indicates that methodological features of
common gambling simulations affect risk taking and that continued research and
development of gambling procedures is needed. Such research may lead not only to the
development of better methods for studying gambling, including methods that have
better ecological validity, but may also help identify new variables that affect gambling.
Figure 1. Gamble-option payout table.
Figure 2. The game table used in all experimental conditions. The participant and experimenter were seated at opposite sides of the table (at the bottom and top of the picture, respectively).
Figure 3. Mean number of gambles placed in the Quit and Pass conditions of Experiment 1 (error bars indicate the standard error of the mean).
Figure 4. Mean experienced percentage payback in the Quit and Pass conditions of Experiment 1.
Figure 5. Mean number of tokens remaining at the end of a session in the Quit and Pass conditions of Experiment 1 (error bars indicate the standard error of the mean).
Figure 6. Mean number of consecutive gambles that occurred prior to a single quit or pass response in the Quit and Pass conditions of Experiment 1.
Figure 7. Mean number of gambles placed in the Quit and Pass conditions across Sessions 1 and 2 of Experiment 1.
Figure 8. Mean number of gambles placed in the Quit and Token Production conditions of Experiment 2.
Figure 9. Number of gambles placed by each participant in the Quit and Token Production conditions of Experiment 2.
Figure 10. Mean experienced percentage payback in the Quit and Token Production conditions of Experiment 2.
Figure 11. Mean number of tokens earned on the token-production option (choices only) and the mean remaining tokens at the end of a session in the Quit and Token Production conditions of Experiment 2.
Figure 12. Mean proportion of choices for the gamble option per opportunity across Participant Stake and Token Production conditions of Experiment 3. The horizontal dashed line indicates the indifference point.
Figure 13. Mean experienced percentage payback in the Participant Stake and Token Production conditions of Experiment 3.
Figure 14. Mean number of tokens earned on the token-production option (from free choices only) and the mean remaining tokens at the end of a session in all conditions of Experiment 3.
Figure 15. Mean proportion of choices for the gamble option per opportunity across Sessions 1 and 2 of both Participant Stake condition orders in Experiment 3. The horizontal dashed line indicates the indifference point.
Figure 16. Proportion of choices for the gamble option per opportunity for each participant across Sessions 1 and 2 of the Stake-Earn and Earn-Stake condition orders in Experiment 3. The horizontal dashed line indicates the indifference point.
Figure 17. Mean proportion of choices for the gamble option per opportunity across Token Production conditions in Experiment 4. The horizontal dashed line indicates the indifference point.
Figure 18. Proportion of choices for the gamble option per opportunity for each participant across Token Production conditions in Experiment 4. The horizontal dashed line indicates the indifference point.
Figure 19. Mean experienced percentage payback in the Token Production conditions of Experiment 4.
Figure 20. Mean number of tokens earned on the token-production option (choices only) and the mean remaining tokens at the end of a session in the Token Production conditions of Experiment 4.
Figure 21. Mean proportion of choices for the gamble option in Sessions 1, 2, and 3 of Experiment 4. The horizontal dashed line indicates the indifference point.
Figure 22. Mean proportion of choices for the gamble option per opportunity at each last stack value across all last stack values in Experiment 4. The horizontal dashed line indicates the indifference point.
REFERENCES


Kassinove, J. I., & Schare, M. L (2001). Effects of the “near miss” and the “big win” on persistence at slot machine gambling. *Psychology of Addictive Behaviors, 15,* 155-158.


Madden, G. J., Dake, J. M. Mauel, E. C., & Rowe, R. R. (2005). Labor supply and consumption of food in a closed economy under a range of fixed- and random-


Appendix

Research Protocol Clearance and Renewal for HSIRB Project Number: 08-02-02
Date: April 16, 2008

To: Cynthia Pietras, Principal Investigator
    Andrew Brandt, Student Investigator for dissertation

From: Amy Naugle, Ph.D., Chair

Re: HSIRB Project Number: 08-02-02

This letter will serve as confirmation that your research project entitled “Choice under Uncertainty” has been approved under the expedited category of review by the Human Subjects Institutional Review Board. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note that you may only conduct this research exactly in the form it was approved. You must seek specific board approval for any changes in this project. You must also seek reapproval if the project extends beyond the termination date noted below. In addition if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: April 16, 2009
Date: April 16, 2009

To: Cynthia Pietras, Principal Investigator
   Andrew Brandt, Student Investigator for dissertation

From: Amy Naugle, Ph.D., Chair

Re: Extension and Changes to HSIRB Project Number 08-02-02

This letter will serve as confirmation that the extension and changes (two experimental manipulations added) to your research project “Choice Under Uncertainty” requested in your memo dated April 15, 2009 have been approved by the Human Subjects Institutional Review Board.

The conditions and the duration of this approval are specified in the Policies of Western Michigan University.

Please note that you may only conduct this research exactly in the form it was approved. You must seek specific board approval for any changes in this project. You must also seek reapproval if the project extends beyond the termination date noted below. In addition if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: April 16, 2010