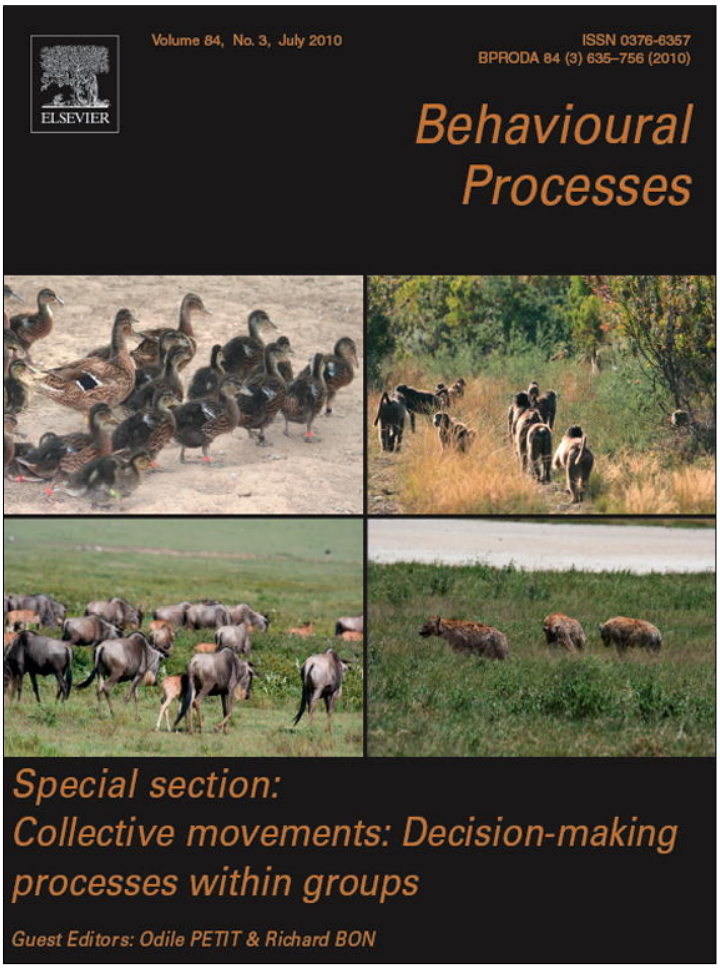

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Probability and delay discounting of hypothetical sexual outcomes

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ABSTRACT

The present study used the discounting procedure to characterize choice behaviors regarding hypothetical sexual outcomes. Eighty-six adult undergraduate students completed computerized delay and probability discounting tasks concerning hypothetical money and hypothetical sexual activity. Consistent with other discounting findings, hyperbolic and hyperbola-like decay models described individual and group median indifference point data well. These findings contribute to a growing literature on the relevance of the discounting procedure to decision-making processes and suggest that the discounting procedure may be useful for understanding the processes that underlie social problem behaviors associated with impulsive sexual decisions.

1. Introduction

1.1. Delay and probability discounting

Delay (or temporal) discounting is the tendency to de-value rewards as a function of the delay to receiving them and is fundamentally tied to behavioral theories of impulsive choice (Ainslie, 1975) in which there is a preference for small, relatively immediate outcomes over larger delayed outcomes. Delay discounting phenomena are well-established in both animal (Mazur, 1988; Green and Estle, 2003; Green et al., 1981) and human (Rachlin et al., 1991; Richards et al., 1999) populations.

In a typical delay discounting procedure in humans, participants make a series of choices between a relatively immediate, but small, outcome and a larger delayed outcome. For example, given the choice between $10 right now and $100 available in 1 day, most people would choose the $100. However, as the smaller amount is adjusted in subsequent questions, most participants eventually "switch" to choosing the smaller amount over the larger amount (e.g., choose $90 right now over $100 in 1 day). The point at which the person switches preference from the delayed to the immediate outcome is called the "indifference point" and represents the current subjective value of the larger outcome at that delay. The series of questions is repeated to establish indifference points across several delays, which typically yield smaller values as the delays increase. Rachlin et al. (1991) extended the discounting procedure to probabilistic outcomes in which individuals choose between relatively small, but certain outcomes and larger probabilistic outcome and the value of the larger outcome decreases as the odds against receiving it increase.

Indifference point data gathered using delay and probability discounting procedures can be described mathematically using a hyperbolic decay model (Eq. (1)) described by Mazur (1987):

$$Y = \frac{A}{1 + bX} \tag{1}$$

In this model,[1] Y represents the subjective value of the delayed outcome, A represents the amount of the large outcome, X represents the delay to (in delay discounting) or odds against (in probability discounting; $[1/p] - 1$, where p = the probability of receiving the large outcome) receiving the large outcome, and b represents a free parameter that indexes the rate of discounting. In the delay discounting task, larger b values indicate a preference for smaller-sooner outcomes (i.e., more impulsive decision-making). In the probability discounting task, smaller b values indicate a preference for probabilistic (i.e., riskier) outcomes.

More recently, Green et al. (1994) advocated for a two-parameter hyperbola-like model, described in Eq. (2):

$$Y = \frac{A}{(1 + bX)^s} \tag{2}$$

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[1] Traditionally, decay functions depicting delay discounting use k to represent discounting rate and D to represent delay. Similarly, decay functions depicting probability discounting use h to represent discounting rate and O to represent odds against. In the interest of brevity, we present the decay models using terms used by others (Estle et al., 2007) that denote the relevant variables for each task.

In this model, the denominator of the hyperbolic function is raised to a power (s) that reflects scaling of time and/or probability (Stevens, 1957). This model tends to provide a significantly better fit to discounting data than do one-parameter models. Moreover, the greater variance accounted for by this two-parameter model is greater than one would expect if the increased variance was due only to adding a free parameter (Bickel et al., 1999; Myerson and Green, 1995).

1.2. Discounting phenomena and non-monetary outcomes

Discounting research using human participants often uses monetary outcomes because money is an easily quantifiable generalized conditioned reinforcer (Critchfield and Kollins, 2001; Perry and Carroll, 2008; Reynolds et al., 2006). Such research has led to important discoveries regarding fundamental behavioral mechanisms that underlie numerous health behavior problems, including obesity (Epstein et al., 2007; Weller et al., 2008), drug use (Bickel et al., 2007), and gambling (Alessi and Petry, 2003; Holt et al., 2003). However, discounting procedures also can characterize choice patterns for non-monetary outcomes such as food (Estle et al., 2007; Odum and Rainaud, 2003; Rasmussen et al., 2009), heroin (Madden et al., 1997), cocaine (Coffey et al., 2003), cigarettes (Bickel et al., 1999), alcohol (Odum and Rainaud, 2003), and even relatively abstract outcomes such as health care utilization (Chapman, 1996; Odum et al., 2002). Measuring stimulus-specific discounting outcomes may improve the understanding and prediction of some problem health behaviors, since some socially important problem behaviors may be differentially associated with choices regarding specific commodities. For example, Rasmussen et al. (2009), recently found that diet-related health outcomes were associated with rate of discounting for food, but not for money.

1.3. Discounting for sexual outcomes

Research only recently has tied discounting phenomena to sexual outcomes, which may have relevance to the study of impulsive sexual decisions. In the only study to date on this issue, Lawyer (2008) found that discounting procedures evoked decision-making patterns for hypothetical erotica that were similar to those for money – at least in some participants – and that the hyperbolic decay model described erotica discounting well. However, decision-making for erotica likely does not serve as a meaningful analogue for sexual decisions more closely tied to socially relevant health outcomes, such as unwanted pregnancy and exposure to sexually transmitted disease.

1.4. Purpose of the present study

The purpose of the present study was to determine if discounting procedures could be used to characterize choice patterns for sexual outcomes that would be generalizable to real-world sexual outcomes. In this study, delay and probability discounting patterns were evoked in relation to hypothetical sexual activity and described using established mathematical decay models. The specific question asked in this study was: can decisions for hypothetical sexual activity be characterized using discounting procedures?

2. Materials and methods

2.1. Participants

Participants were undergraduate students ($n = 89$) recruited from introductory psychology courses. Data for three participants were excluded from analyses due to technical problems with the task ($n = 1$) or because the participants ($n = 2$) elected to stop data collection before completing all discounting tasks. Of the remaining participants, the majority were female ($n = 57$; 66.3%) and the average age of all participants was 26.0 years (SD = 9.5; range = 18–63). Most participants reported Caucasian ethnicity ($n = 71$; 82.6%), while others reported Hispanic ($n = 11$; 12.8%), "other" ($n = 3$; 3.5%), or African-American ($n = 1$; 1.2%) ethnicities. The majority of participants ($n = 82$; 95.3%) reported some form of religious affiliation. In terms of relationship status, 40.7% ($n = 35$) reported being married, while the rest reported being single/never married ($n = 37$; 43.0%), divorced (8.1%; $n = 7$), or unmarried but living with his/her partner (7%; $n = 6$). Almost all of the participants identified as heterosexual (96.5%; $n = 83$). All participants received a small amount of course credit for their participation.

2.2. Discounting tasks

2.2.1. Delay and probability discounting for money

Rates of discounting for money were established using a computerized discounting program and procedure similar to that used in previous studies (Lawyer, 2008; Richards et al., 1999). A research assistant read the following script before data collection began:

> In the task that follows, you will have the opportunity to choose between different amounts of money available after different delays or with different probabilities. The test consists of questions such as the following: (a) "Which do you prefer?: $2 for sure or $10 with a 50% chance" and (b) "Which do you prefer?: $3 right now or $10 in 1 month?." You will not receive any of the rewards that you choose, but we want you to make your decisions as though you were really going to get the rewards you choose.

A series of forced-choice options was presented to participants. For the delay discounting task, participants chose between $10 to be received after each of six delays (1, 2, 7, 30, 180, and 365 days) and a smaller amount of money available immediately. For the probability discounting task, participants chose between $10 available with some probability (95%, 75%, 50%, 25%, 10%, 5%) and a smaller amount of money available "for sure." After each choice, the computer program narrowed the range of values on successive choice trials by incrementally adjusting the smaller amount of money up or down (±$0.50) until an indifference point was established (see Richards et al., 1999, for details regarding the double-limit method). All delay and probability discounting questions were intermixed and delivered in a single session. Indifference point values were used to fit discounting functions to individual and group median indifference point data.

2.2.2. Delay and probability discounting for sexual activity

Delay and probability discounting for sexual activity was measured using the same computer task used in the money tasks. Prior to data collection, a research assistant read the following script:

> In the task that follows, you will have the opportunity to choose between different amounts of sexual activity available after different delays or with different probabilities. The test consists of questions such as the following: (a) "Which do you prefer?: 2 min of sexual activity for sure or 10 minutes with a 50% chance" and (b) "Which do you prefer?: 3 minutes of sexual activity right now or 10 minutes of sexual activity in 1 week?." "Sexual activity" means different things for different people, but you should answer each question in terms of whatever kind of sexual activity you personally find very appealing. You will not receive any of the rewards that you choose, but we want you to make your decisions as though you were really going to get the rewards you choose.

Table 1
Frequency of nonsystematic response patterns across discounting tasks.

	Algorithm				Visual inspection			
	1	2	Both	Either	Anomalous[a]	Flat	Random	Reverse
Delay money	6	7	1	12	3	3	6	0
Probability money	11	7	4	14	7	2	3	2
Delay sexual activity	16	15	7	24	5	10	9	0
Probability sexual activity	16	17	8	25	6	5	13	1

[a] These participants were retained for further analysis, since they included only a single data point in an otherwise clear pattern of discounting.

After participants indicated they understood the task, they completed the delay and probability discounting tasks in relation to sexual activity. The large amount of sexual activity used for both tasks was 10 min and indifference points were established using the same delays and probabilities used in the money tasks. The computer program established indifference points for all delays and probabilities using the same procedure as in the money task; adjusting increments were set at ±0.5 min. As in the money tasks, delay and probability discounting questions were intermixed and delivered in a single session. Indifference point values were used to calculate discounting rates and to fit discounting functions to individual and group median indifference point data.

2.3. Procedure

After providing written consent for their participation, participants provided basic demographic information and completed all behavioral measures in a private office containing a desk, chair, and a computer. The order of behavioral measures was counterbalanced to control for order effects.

2.4. Analyses

2.4.1. Identifying nonsystematic responders

Nonsystematic response patterns, which indicate anomalous responding due to either carelessness (e.g., random responding) or invariance in responding (e.g., indifference values do not change as a function of delay or probability), were identified using two algorithms described by Johnson and Bickel (2008). Specifically, an individual's data were identified as "nonsystematic" if (1) any one indifference value was greater than the preceding indifference value by more than $2 (in the money task) or 2 min (in the sexual activity task); or (2) the last indifference value was not less than the first by at least $1 (in the money task) or 1 min (in the sexual activity task). These algorithms were applied to each of the four discounting tasks for every participant. After nonsystematic response patterns were selected using these algorithms, visual inspection of individual data revealed several instances where nonsystematic responders identified using algorithm 1 had a single wayward data point in the context of a clear pattern of discounting for delayed or probabilistic outcomes. Therefore, these data were retained for further analysis. McNemar's χ^2-test, which is used with non-independent cell frequencies, was used to test for proportional differences in the frequencies of nonsystematic responders in the money versus sexual activity tasks.

2.4.2. Estimating discounting parameters

Individual and group median indifference point data were fit to hyperbolic (Eqs. (1) and (2)) and hyperbola-like (the denominator of the hyperbolic functions raised to the power s; Myerson and Green, 1995) discounting functions using nonlinear regression procedures (SPSS 14.0; 2005), which generate goodness-of-fit indicators (R^2) for each function in relation to individual and group median data, rates of decay (b) for delayed and probabilistic outcomes, and an index (s) of the scaling (Stevens, 1957) of amount, time, delay, or probability in the hyperbola-like function. In addition, area under the curve (Myerson et al., 2001) estimates, which provide a theoretically neutral measure of discounting rate were calculated.

3. Results

3.1. Systematic and nonsystematic response patterns

McNemar's χ^2-test revealed that although there were twice as many nonsystematic response patterns in the sexual activity delay discounting task ($n = 19$; 22.1%) than in the money discounting tasks ($n = 9$; 10.5%), this difference only approached significance ($p = .064$). However, probability discounting for sexual activity yielded more nonsystematic response patterns ($n = 19$; 22.1%) than did probability discounting for money ($n = 3$; 3.5%) ($p < .05$). To better describe the discounting patterns associated with nonsystematic responders, the frequency of participants identified as nonsystematic by each algorithm (or both) is presented in Table 1. In addition, individual nonsystematic data were inspected visually and categorized as either flat (little or no variation as a function of delay or probability), random (no clear pattern, multiple anomalous data), or reverse (a clear pattern of increasing the value of outcomes as the delay to or odds against receiving them increased).

3.2. Individual and group median indifference point data

Table 2 shows the median discounting parameters when fitting hyperbolic and hyperbola-like decay models to individual indifference point data among systematic responders within each task. Fig. 1 shows group median values across delays and probabilities within each task and the associated fits of the hyperbolic and hyperbola-like decay models. Delay and probability discounting for hypothetical sexual activity yielded patterns of median indifference point values that resemble those for money. Both models provided a good fit to median indifference point data regarding both money and sexual activity (all R^2 values ≥ 0.95). For descriptive purposes, frequency distributions for AUC estimates are shown in Fig. 2.

4. Discussion

The purpose of the present study was to determine whether the delay and probability discounting procedure could be used to characterize choice behaviors regarding hypothetical sexual activity. After nonsystematic response patterns were excluded, individual and group median indifference point data were fit to standard discounting functions to assess their ability to characterize impulsive decisions for hypothetical sexual outcomes. Results of this study support the use of the discounting procedure for studying impulsive decisions for hypothetical sexual outcomes in a laboratory context.

Table 2
Median discount rate and R^2 values estimated using hyperbolic and hyperbola-like functions fit to individual indifference points among systematic responders. Parenthetical values represent 25th and 75th percentiles.

Commodity/task	Hyperbolic		Hyperbola-like		
	b	R^2	*b*	*s*	R^2
Money					
Probability (*n* = 79)	1.8 (.90, 3.5)	.86 (.69, .95)	5.95 (2.13, 13.44)	.55 (.38, 1.0)	.93 (.84, .96)
Delay (*n* = 77)	.04 (.01, .11)	.90 (.70, .95)	.11 (.05, .57)	.66 (.29, 1.0)	.93 (.74, .96)
Sexual activity					
Probability (*n* = 67)	1.36 (.63, 3.85)	.78 (.38, .91)	11.61 (2.0, 40.3)	.46 (.23, .89)	.89 (.75, .95)
Delay (*n* = 67)	.07 (.02, .35)	.84 (.46, .94)	.37 (.07, .83)	.80 (.27, 1.0)	.87 (.78, .94)

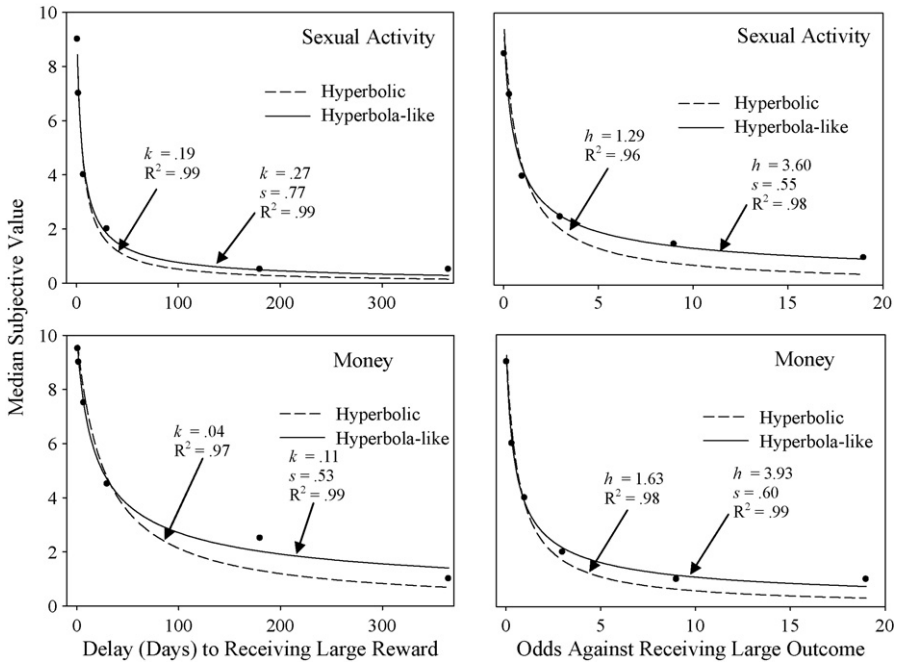

Fig. 1. Median indifference values for systematic responders within delay (left) and probability (right) discounting tasks for sexual activity (upper figures) and money (lower figures). Lines represent fit for hyperbolic (dashed) and hyperbola-like (solid) decay models.

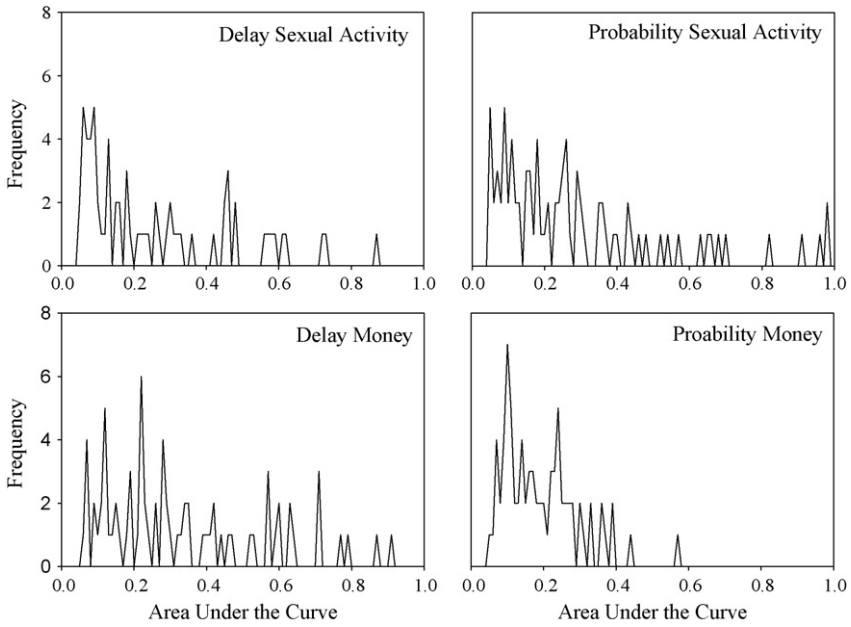

Fig. 2. Frequency distributions for area under the curve (AUC) estimates across tasks.

4.1. Characterizing decisions for hypothetical sexual activity using the discounting procedure

The findings presented here suggest that the discounting model can be used to characterize decisions for sexual activity. Although discounting for sexual activity was generally more likely to produce nonsystematic response patterns, the majority of participants provided discounting data in relation to hypothetical sexual activity that were described well using standard decay models at both the individual and group median level. These results extend Lawyer's (2008) findings regarding discounting the value of hypothetical erotica outcomes and suggests that discounting procedures can be used to study ecologically valid sexual outcomes, which may provide a theoretically and experimentally meaningful way to better understand the processes that underlie a variety of sexual decisions.

This study also adds to a growing research literature regarding discounting of non-monetary outcomes in human participants. Money discounting provides important information regarding patterns of impulsive choice, but there are theoretical and empirical reasons for assessing stimulus-specific choice patterns. For example, reliance upon discounting for money as a measure of impulsive choice assumes that impulsive decision-making is a stable trait that will be evident across all types of outcomes. However, Weber (2001) has argued for a more dynamic view of decision-making behavior in which choice patterns likely vary as a function of the outcome. Consistent with this, Rasmussen et al. (2009) found that percent body fat was associated with discounting for food, but not money. This suggests that decision-making procedures should use stimulus-specific outcomes to best understand the behavioral processes that underlie relevant health outcomes (cf, Davis et al., 2009; Weller et al., 2008). Developing methods to study stimulus-specific outcomes also provides important opportunities to test behavioral theories of choice (e.g., Loewenstein, 1996) that predict stimulus-specific response patterns under transient conditions (e.g., when hungry versus sexually aroused).

4.2. Systematic and nonsystematic response patterns

The findings support Johnson and Bickel's (2008) suggestion that *a priori* and theoretically neutral algorithms are useful for investigating the circumstances under which differential frequencies of systematic response patterns are found. In this study, discounting for sexual activity was more likely to produce nonsystematic response patterns for probabilistic outcomes than was discounting for money and there was a similar trend in the delay discounting tasks. There are several possible reasons for these outcomes. Since participants were not screened with regard to their interest in engaging in sexual activity, it is possible that some participants (e.g., those practicing abstinence) did not view sexual activity as a rewarding outcome. There are possible procedural confounds as well. It also is possible that the 10 min of sexual activity used as the large outcome was viewed as too small (perhaps leading to sexual frustration) by some or too much (leading to overstimulation) by others, either of which may increase the probability of nonsystematic responding. In addition, the delays used in the delay discounting task (1–365 days) may have influenced nonsystematic response patterns either because they were too short or too long to capture variance in responding. At any rate, future research might consider including only those participants for whom sexual activity is a reward, manipulating the amount of the sexual activity (e.g., 5 min, 30 min) and delay periods (e.g., hours) to increase the rates of systematic response patterns.

4.3. General conclusions and future directions

The results of the present study suggest that choice behaviors regarding hypothetical sexual activity can be characterized using delay and probability discounting methods. These findings confirm Logue's (2000) suggestion that the discounting procedure may be useful for studying sexual decision-making. The extent to which discounting for sexual activity provides an opportunity to better understand real-world sexual behaviors remains to be seen, though the findings here provide some optimism. Numerous studies examining methodological aspects of discounting have been published in recent years (Madden et al., 2003; Robles et al., 2009) and future research concerning discounting for sexual outcomes should include methodological studies aimed at identifying the parametric aspects of the task (e.g., size of the outcomes, length of delays) that yield the most consistent and systematic data. Such studies might also identify screening criteria that would exclude participants who respond in an anomalous (i.e., nonsystematic) manner to such tasks, which would enhance the internal validity of research using this measure.

Future research might also consider examining how one type of a delayed and/or probabilistic negative outcome might mitigate an individual's preference for a different type of delayed and/or probabilistic outcome. Green and Myerson (2004) point out that many of life's choices involve both positive and negative outcomes, such as when palatable, high-fat, foods lead to immediate gratification but long-term health risks. Several studies to date describe discounting of negative outcomes (e.g., loss of a reinforcer; Murphy et al., 2001), but none to date have examined how complex environmental scenarios involving both positive and negative outcomes influence behavioral choices. Such efforts in the context of sexual decision-making may be especially important in light of data suggesting that some sexual behaviors (i.e., sexual risk-taking) are less associated with a sensitivity to positive outcomes (e.g., sexual stimulation) than an insensitivity to negative sexual outcomes (e.g., disease exposure) (Bancroft et al., 2009).

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