

Original Article

Does Fertility Status Influence Impulsivity and Risk Taking in Human Females? Adaptive Influences on Intertemporal Choice and Risky Decision Making

Farnaz Kaighobadi, HIV Center for Clinical and Behavioral Studies at New York State Psychiatric Institute and Department of Psychiatry at Columbia University, New York, USA. Center for Adaptive Behavior and Cognition, Max Planck Institute for Human Development, Berlin, Germany; Email: fk2281@columbia.edu (Corresponding author).*

Jeffrey R. Stevens, Center for Adaptive Behavior and Cognition, Max Planck Institute for Human Development, Berlin, Germany; Department of Psychology, University of Nebraska-Lincoln, Lincoln, Nebraska, USA; Email: jeffrey.r.stevens@gmail.com.*

*Both authors contributed equally to this work.

Abstract: Informed by the research on adaptive decision making in other animal species, this study investigated human females' intertemporal and risky choices across the ovulatory cycle. We tested the hypothesis that at peak fertility, women who are exposed to environments that signal availability of higher quality mates (by viewing images of attractive males), become more impulsive and risk-seeking in economic decision tasks. To test this, we collected intertemporal and risky choice measures before and after exposure to images of either attractive males or neutral landscapes both at peak and low fertility conditions. The results showed an interaction between women's fertility status and image type, such that women at peak fertility viewing images of attractive men chose the smaller, sooner monetary reward option less than women at peak fertility viewing neutral images. Neither fertility status nor image type influenced risky choice. Thus, though exposure to images of men altered intertemporal choices at peak fertility, this occurred in the opposite direction than predicted—i.e., women at peak fertility became less impulsive. Nevertheless, the results of the current study provide evidence for shifts in preferences over the ovulatory cycle and opens future research on economic decision making.

Keywords: decision making, impulsivity, intertemporal choice, ovulatory cycle, risky choice

Introduction

Should a female peahen mate with her current partner or spend the time and run the risk associated with finding a new mate? Animals must constantly choose between options in which outcomes vary in the timing of receipt (intertemporal choice) and probability of receipt (risky choice). Given the frequent nature of these decisions, natural selection has likely shaped adaptive mechanisms to solve these important problems (Hammerstein and Stevens, 2012). The animal behavior and animal cognition literature has explored various adaptive benefits associated with economic decisions such as intertemporal and risky choice. Fewer studies have explored the adaptive nature of intertemporal and risky choice in humans. In this article, we first review adaptive accounts of intertemporal and risky choice in animals to highlight the critical but underappreciated evolutionary perspective on these decisions. We then identify situations in which an evolutionary perspective may illuminate mechanisms underlying human decision making. In particular, we assess whether a woman's conception risk and potential mating opportunities interact to alter the intertemporal and risky choices that she makes. To investigate these issues, we experimentally tested hypotheses about women's decision making in the mating domain across the ovulatory cycle.

Adaptive decision making in other animals

Intertemporal choices involve deciding between smaller options available sooner and larger options available later (Read, 2004; Stevens, 2010a). Historically, psychologists have treated temporal preferences as if waiting longer always results in better outcomes. Work on "delayed gratification" shows that children who can wait longer for delayed rewards experience better outcomes in life. Patient children perform better in school and on standardized tests and have reduced substance abuse problems and divorce rates in adulthood (Ayduk et al., 2000; Duckworth and Seligman, 2005; Mischel, Shoda, and Rodriguez, 1989). However, waiting may not always be the best strategy. An adaptive approach to intertemporal choice explores the conditions or contexts under which impulsivity versus patience pays off (Fawcett, McNamara, and Houston, 2012; Stevens and Stephens, 2009).

One important reason to choose immediate over delayed rewards is that the delayed rewards may not be available later; that is, the receipt of delayed rewards may be interrupted due to competition, weather, or death. The uncertainty of the future may result in higher fitness outcomes for choosing more immediate payoffs. Parasitic wasps (*Leptopilina heterotoma*), for instance, dump all of their eggs in one host (resulting in more sibling competition) rather than spreading them over multiple hosts when the atmospheric pressure drops (Roitberg, Sircom, Roitberg, van Alphen, and Mangel, 1993). Thus, they appear to be sensitive to the potential interruption of laying future eggs due to poor weather approaching.

A final adaptive account of intertemporal choice uses a comparative perspective to explore how an organism's foraging ecology shapes its decision mechanisms. If species differ in the prevalence of intertemporal choices in their environment, they may differ in their baseline temporal preferences. Cotton-top tamarins (*Saguinus oedipus*) and common

marmosets (*Callitrix jacchus*), for example, are phylogenetically closely related New World monkeys that share many aspects of their life history, ecology, and behavior. They differ, however, in their reliance on tree exudates in their diet, a food source that requires waiting for the sap to exude (Snowdon and Soini, 1988; Stevenson and Rylands, 1988). In laboratory tests of intertemporal choice, the exudate specialist marmosets waited longer than the more insectivorous tamarins (Stevens, Hallinan, and Hauser, 2005). Similarly, the difference between chimpanzees (*Pan troglodytes*) and bonobos (*Pan paniscus*) in their hunting tendencies has implications for intertemporal choice: Chimpanzees hunt more often than bonobos (Stanford, 1998; Wrangham and Pilbeam, 2002). Hunting requires waiting to capture prey, so hunters may tend to have more patient temporal preferences than non-hunters. Experimental results match the foraging ecology predictions, with chimpanzees waiting longer than bonobos in an economic foraging task (Rosati, Stevens, Hare, and Hauser, 2007). Thus, existing species comparisons suggest that the foraging problems that animals face shape their intertemporal choice decision mechanisms.

Risky choice involves choosing among options with different degrees of variability in receipt of reward (Wu, Zhang, and Gonzalez, 2004). Would you prefer a smaller option that is certain or a chance at a larger option? The study of risky choice in animals has been tightly linked to optimal foraging theory (Stephens and Krebs, 1986), in which animals choose an optimal policy to cope with repeated foraging opportunities. Under this framework, researchers have investigated risky choice in a larger number of species, ranging from bees and wasps to rodents and primates (Kacelnik and Bateson, 1996). In general, animals tend to be fairly risk averse; that is, they tend to prefer safe options over risky ones when the average payoff (probability multiplied by reward amount) is equal. This makes economic and evolutionary sense (Stephens and Krebs, 1986) for rewards that yield diminishing returns, such as food—an additional gram of food is more valuable to an organism when it has little food compared to when it has much food (see Stevens, 2010b).

Despite this overall trend of risk aversion, variation in risk preferences exists both within and between species, with possible adaptive explanations. Adaptive risk preferences within an individual may occur depending on hunger level. A very hungry individual may choose a risky option when the safe option will not meet its metabolic needs (Stephens, 1981). Caraco, Martindale, and Whittam (1980) found that yellow-eyed juncos (*Junco phaeonotus*), in fact, did become more risk seeking when they had lower energy reserves. This finding, however, has not generalized across all species (Kacelnik and Bateson, 1996). Moreover, chimpanzees demonstrated the opposite pattern by hunting (a risky activity in terms of success rate) more often when fruit was abundant in their environment compared to when it was scarce (Gilby and Wrangham, 2007). This finding suggests more of a U-shaped function, in which organisms seek risks under dire energetic circumstances or when the environment is rich enough that one can afford risks. At intermediate states of the world, organisms tend to avoid risks.

Comparing behavior between species can also aid our understanding of intertemporal choice. For instance, because chimpanzees more frequently face the risky outcomes associated with hunting compared to bonobos, chimpanzees may have evolved risk preferences that match the level of risk experienced in their natural foraging environment. Experimental comparisons of risky choice between these two species suggest

that chimpanzees also seek risks more than bonobos in economic foraging tasks (Haun, Nawroth, and Call, 2011; Heilbronner, Rosati, Stevens, Hare, and Hauser, 2008; Rosati and Hare, 2011, 2012). Thus, like temporal preferences, risk preferences may provide adaptive responses to environmental variation.

Human intertemporal and risky choice as adaptations

Though the bulk of work on evolutionarily adaptive decision making has focused on other animals, recent research has emphasized adaptations in human decision making. Most of these studies investigate the role of decision making in the mating context. For instance, Smith et al. (2009) explored the role of attractiveness in cooperative situations and found that more attractive individuals are more sensitive to whether they can be observed in trust games. Also, people are more likely to reciprocally cooperate with healthy-looking partners (Krupp, DeBruine, and Barclay, 2008). Thus, to the extent that healthy faces are used as a cue for potential mating partners, we have hints that mating contexts are important in cooperative situations. The effect of mating context on individual decision making situations such as intertemporal and risky choice, however, remains less clear.

In the temporal domain, Wilson and Daly (2004) tested intertemporal choice in an adaptive context by inducing a “mating opportunity mindset” in men and women by having them view images of attractive members of the opposite sex. After viewing these images, participants increased their impulsive choices (choices for the smaller, sooner option) in a monetary choice task, suggesting that the images induced a preference for immediate payoffs. Though clear for men, the effect was not as strong for women. Nevertheless, Wilson and Daly conclude that viewing attractive members of the opposite sex induces a mating mindset that enhances impulsive decision making in intertemporal choices. The weaker effect in women, however, leaves open the possibility that including conception risk in the analysis may clarify the influence of mating context on women’s intertemporal choices.

Of particular importance for risky choice is the recent research suggesting that women’s sexual motivation, mate choice, and sexual behavior change across the ovulatory cycle (e.g., Gangestad, Thornhill, and Garver-Apgar, 2005a; Haselton and Gangestad, 2006; Haselton, Mortezaie, Pillsworth, Bleske-Rechek, and Fredrick, 2007). Between-and within-cycle differences in estradiol levels predict likelihood of pregnancy. Pregnancy is more likely to occur in cycles marked with higher levels of estradiol and also at mid-cycle when estradiol reaches its maximum level. Thus, brain mechanisms may use estradiol levels as a marker of the likelihood of conception (see Roney and Simmons, 2008 for review). The *ovulatory shift hypothesis* suggests that women may possess adaptations that make them sensitive to that limited window of peak fertility when risk of conception is the highest (Gangestad and Thornhill, 1998). Women might have evolved psychological mechanisms that produced adjustments in their sexual desire and behavior as a function of conception risk (Gangestad et al., 2005a).

Numerous research studies have provided evidence for the ovulatory shift hypothesis. For example, near ovulation, women’s preference for male signals of genetic quality increases, arguably because the genetic quality of a sexual partner can directly influence the genetic quality of resulting offspring (Feinberg et al., 2006; Gangestad,

Garver-Apgar, Simpson, and Cousins, 2007; Gangestad, Thornhill, and Garver-Apgar, 2005b; Little, Jones, and Burris, 2007; Penton-Voak et al., 1999). Women's sexual motivation (in women with or without sexual partners) and sexual activity increase during the fertile phase of their ovulatory cycle (Bullivant et al., 2004). Women at peak fertility are more likely to "dress to impress" (Haselton et al., 2007) and report more desire to go to events and places where they are likely to meet men (Haselton and Gangestad, 2006).

Two previous studies have applied the ovulatory shift hypothesis to women's risk-taking behavior across the ovulatory cycle (Bröder and Hohmann, 2003; Chavanne and Gallup, 1998). According to both studies, women engage in fewer risky behaviors, such as walking alone in the dark, during the peak fertility phase of the cycle. Avoiding these risky behaviors minimizes the chances of rape when the risk of conception is high. In contrast to these two studies, Pearson and Schipper (2013) documented an increase in women's risky choices in a bidding game at peak fertility. They argued that studies that have documented a decrease in risky behavior at peak fertility have measured such behavior in the "sexual loss" domain (e.g., rape), and that women may in fact engage in riskier behaviors if there is likelihood of a "sexual gain" associated with mating with higher quality partners.

The present study

Apart from this handful of studies, little research explores whether women possess adaptations that alter their economic choices, such as intertemporal and risky choices, across the ovulatory cycle. Women's access to resources in a competitive mating market may increase their chances of accessing higher quality mates, especially when the risk of conception is high. In fact, previous research has shown that ovulatory cycle status and availability of mating competition affect women's choice of products, motivating them to buy "sexier" products (Durante, Griskevicius, Hill, Perilloux, and Li, 2011). Thus, women may make different economic decisions depending on the conception risk, availability of resources, mating competition, and quality of the mating market.

In the present study, we extend previous work by testing (1) Wilson and Daly's (2004) hypothesis that women become more temporally impulsive when induced with a "mating mindset" and (2) Pearson and Schipper's (2013) suggestion that at peak fertility women will take more risks when facing gains. Both the Wilson and Daly and the Pearson and Schipper studies emphasize that changes in decision making are context dependent. Rather than general mechanisms that apply across contexts, choices are especially sensitive to the potential for mating opportunities. Wilson and Daly induced a mating mindset to make participants more temporally impulsive in order to take advantage of available mating opportunities. They did not, however, take into account women's fertility status. Considering the effects of ovulation status on women's mating decisions, we speculate that Wilson and Daly's study may have resulted in different outcomes had they measured and accounted for conception risk. Therefore, to address the gap in Wilson and Daly's study, we tested women's temporal preferences across the ovulatory cycle. In addition, we extend Pearson and Schipper's work by examining risky choices made in a monetary domain. We measured women's risky choices in standard economic gambles as we induced a mating mindset in women (gaining potential access to quality mates) across the ovulatory cycle.

To investigate how temporal and risk preferences change with fertility status, we

measured women's behavioral changes across the ovulatory cycle using two tasks: (1) the *intertemporal choice task*, which measures women's preference for a small but immediate monetary reward versus a larger but delayed monetary reward, and (2) the *risky choice task*, which measures women's risk taking by asking them to choose between monetary choices of different amounts and probabilities. We compared women in an experimental group, who viewed images of attractive men to elicit a potential mating domain, to women in a control group who viewed neutral images of landscapes.

Our overall hypothesis is that conception risk and mating context interact in influencing economic decision making in women. Specifically, when primed for a "mating mindset" by viewing images of attractive men, women at peak fertility will make more impulsive and risky choices compared to when at low fertility. Thus, for the intertemporal choice task, we predict an interaction such that, unlike women viewing images of landscapes, women viewing images of attractive men will choose the smaller, sooner reward more at the peak fertility phase of the ovulatory cycle compared to low fertility. Similarly, for the risky choice task, we predict that only women viewing images of attractive men will choose the risky reward more at the peak fertility phase of the ovulatory cycle compared to low fertility.

Materials and Methods

Participants

Out of 41 women who participated in this study, 28 completed both experimental sessions. The eligibility for participation included (1) being 18 years of age or older, (2) being heterosexual or bisexual, (3) having a regular menstrual cycle, (4) not taking any hormonal contraceptives (e.g., birth-control pills, shots, patches, etc.) for the past 3 months, and (5) not being pregnant or nursing. Women in this study were recruited from June 2010 to April 2011 in psychology courses at Florida Atlantic University. They participated for course credit and a monetary reward that was determined by their answer to a randomly pre-selected intertemporal or risky choice task question. The mean age of participants was 25.5 years (range: 19-44 years).

Procedures

Each participant was asked to complete three sessions, including an ovulatory phase estimation session and two experimental sessions (one during the high fertility phase and one during the low fertility phase). At the beginning of the phase estimation session, the participants read and signed the consent form that confirmed their eligibility for participation and their agreement to participate. Ethical compliance of the procedures was reviewed and approved by the Institutional Review Board at Florida Atlantic University.

Phase estimation session

Based on participants' first day of last menstrual cycle and menstrual cycle length, the experimenter used the backward counting method, similar to previous research (e.g., Haselton and Gangestad, 2006) to estimate participants' ovulatory cycle. The peak fertility phase included the day 15 days prior to the first day of the next menstrual cycle and the

four days prior to that. The low fertility phase was estimated to be between 2 days after the peak fertility phase and 3 days before the next menstrual cycle. The first experimental session was scheduled for the closest-in-date phase of the cycle. The two sessions were about two weeks apart.

To confirm high fertility status, each participant received five commercially available urine-based luteinizing hormone (LH) predictor test kits to take home. The participant was asked to follow the instructions and to test her fertility status on the estimated high fertility days and call the lab once she obtained positive results. The participant was then scheduled for the high fertility experimental session on that day or the day after. This is because the LH surge occurs 24-48 hours prior to ovulation, and for the purpose of this study, we were interested in testing participants either on the day of LH surge or the day of ovulation. If 5 days passed and we did not detect the LH surge, the participant was dropped from the study.

The phase estimation session also consisted of completing a number of questionnaires, including demographic information, relationship status, and relationship length.

Experimental sessions

Each participant was tested individually during both experimental sessions. Participants completed all tasks on a computer using the custom-made program Disc'n'Risk by Uwe Czienskowski. Each experimental session included completing the intertemporal choice and risky choice tasks at baseline and after rating the attractiveness of images, in the following order:

(1) *Pre-exposure intertemporal choice task*: The participant was instructed to choose one option among a pair of monetary options varying in amount and delay in receiving the reward (e.g., "\$1 today versus \$10 in 28 days") by clicking on the option of choice. The question was followed by a series of choices increasing in the amount of money received today (e.g. "\$2 today versus \$10 in 28 days" up to "\$10 today versus \$10 in 28 days"). Each participant experienced seven blocks of 10 pairs of options (questions available in Supplementary Materials).

(2) *Pre-exposure risky choice task*: The participant was presented with a pair of monetary options varying in amount and probability of receipt (e.g. "1/10 chance of \$16.69 versus 5/10 chance of \$18.33"). The participant was instructed to choose one by clicking on her option of choice. The question was followed by a series of choices, ascending in probability of receipt (e.g. "2/10 chance of \$16.69 versus 5/10 chance of \$18.33" up to "10/10 chance of \$16.69 versus 5/10 chance of \$18.33"). Each participant experienced five blocks of 10 pairs of options (questions available in Supplementary Materials).

(3) *Image ratings task*: Each participant was instructed either to rate the sexual attractiveness of images of 20 men (to make the "mating mindset" salient) or to rate the attractiveness of 20 landscape images. For male images, the participants rated the "physical attractiveness" of each man on a scale of 0 ("not at all attractive") to 9 ("very attractive"). For neutral images, the participants rated the beauty of each landscape image on a scale of 0 ("not at all beautiful") to 9 ("very beautiful"). Both sets of images came from search results in Google Image search engine. To select men's images, author FK searched for

images of “male models” and selected 20 images that represent different racial or ethnic backgrounds. All images were taken from waist up, including 11 men not wearing shirts. Half of the images were in black and white and half were in color. None of the men were smiling in the images and, with the exception of two, all men were looking into the camera. To select neutral images, author FK searched images of “landscapes” and randomly picked 20 images. To counterbalance the experimental conditions, participants with an odd participant number were assigned to the neutral image condition and participants with an even participant number were assigned to the male image condition.

(4) *Post-exposure intertemporal choice task*: The participant completed the intertemporal choice task for the second time. With the exception of one block of questions, the amounts and delays used in the blocks differed between baseline and post-exposure tasks. The one block of questions shared across baseline and post-exposure tasks was used as the key measure of intertemporal choice (see Data Analysis).

(5) *Post-exposure risky choice task*: The participant completed the risky choice task for the second time. With the exception of one block of questions, the amounts and probabilities used in the blocks differed between baseline and post-exposure tasks. The one block of questions shared across baseline and post-exposure tasks was used as the key measure of risky choice (see Data Analysis).

Data analysis

We analyzed the data using R statistical software version 2.15.2 (R Development Core Team, 2012) and the boot (Canty and Ripley, 2012), epicalc (Chongsuvivatwong, 2012), Hmisc (Harrell, 2012), lattice (Sarkar, 2008), latticeExtra (Sarkar and Andrews, 2011), and nparLD (Noguchi, Gel, Brunner, and Konietzschke, 2012) packages. Data and R code are available as Supplementary Materials, and data are available at the Dryad data repository (doi:10.5061/dryad.490r9).

Though participants experienced seven blocks of intertemporal choices and five blocks of risky choices, six of the intertemporal choice blocks and four of the risky choice blocks acted as distractors in which all of the questions differed across all four instances of each task (pre- and post-exposure for peak and low fertility). One block of intertemporal choice questions and one block of risky choice questions were used in all four instances of these tasks: \$X today or \$10 in 28 days and an X/10 chance of \$16.69 or a 5/10 chance of \$18.33. For each instance of both of these blocks, we calculated the point at which participants switched choice from the larger reward to the smaller reward as their indifference point. For intertemporal choice, this indifference point indicated how much money available today was equivalent to \$10 in 28 days. Thus, as the indifference point decreased, people became more impulsive. For risky choice, this indifference point indicated the probability of receiving \$16.69 that was equivalent to a 50% chance of receiving \$18.33. As the indifference point decreased, people became more risk seeking.

We used two versions of the indifference points as dependent variables. The first *baseline indifference points* included only the pre-exposure data. This allowed an overall assessment of intertemporal and risky choice before the attractiveness ratings. The second measure calculated the *difference scores* between post-exposure – pre-exposure to the attractiveness ratings, which measured the impact of the images on choice (more negative

values mean preferences changed to more impulsive or more risk-seeking choice). To calculate within-subject effects, we used only data from participants ($n = 28$) who completed both experimental sessions (both peak and low fertility conditions). Due to difficulties with acquiring participants, they were not evenly distributed between the two image type conditions (male image: $n = 11$, neutral image: $n = 17$). In all analyses, residuals departed significantly from a normal distribution, violating the assumptions of the ANOVA. Therefore, we used nonparametric statistics for all analyses. Means are given with 95% confidence intervals using a bootstrap technique, with 999 draws using the normal approximation method.

Results

Attractiveness ratings

Previous research has demonstrated much variation and relatively little consensus among women rating pictures of men on attractiveness (Wood and Brumbaugh, 2009). Wilson and Daly (2004) also found that women rated images of men (intended to be attractive men) as average. In our study, women rated images of men slightly above average in attractiveness both at peak and low fertility phases of the cycle (see Table 1). Due to a technical error, data from one participant in the male image condition is missing.

Table 1. Mean \pm 95% CI attractiveness ratings of images

Condition	Fertility Status		Mean
	Peak	Low	
Male image*	4.6 \pm 0.9	5.1 \pm 1.0	4.9 \pm 0.7 ($n = 20$)
Neutral image	6.1 \pm 0.6	6.5 \pm 0.6	6.3 \pm 0.4 ($n = 34$)
Mean	5.6 \pm 0.6 ($n = 27$)	6.0 \pm 0.6 ($n = 27$)	

Note: * One participant from the male image condition was not included due to a technical error.

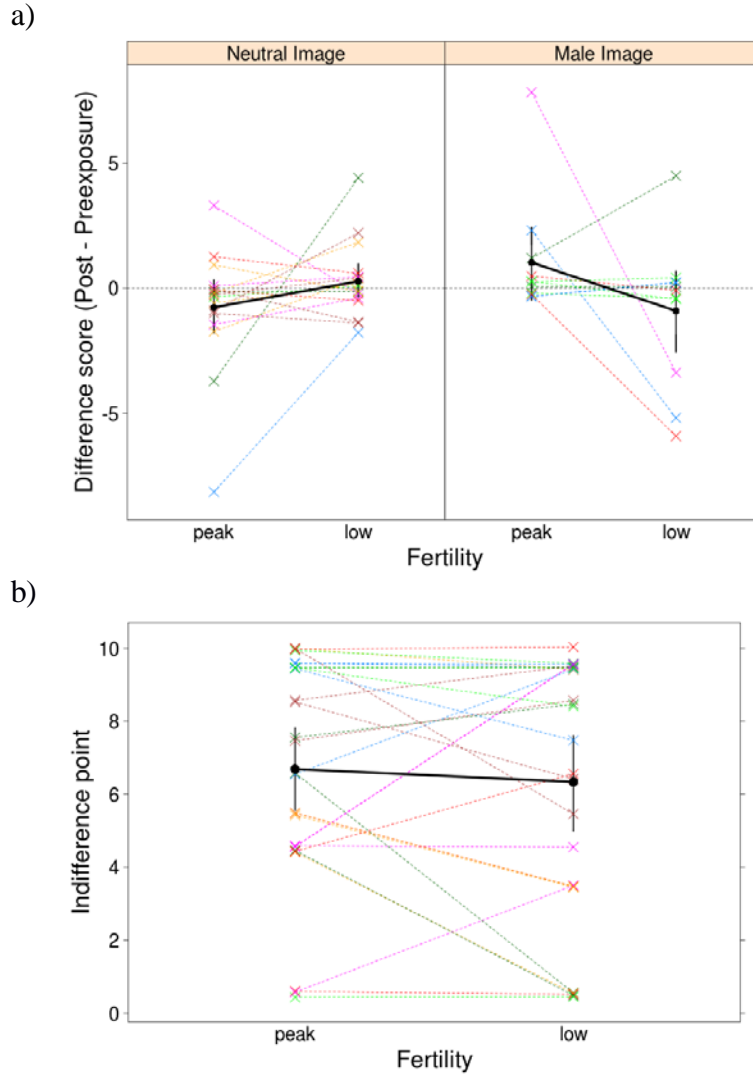
Intertemporal choice

To test whether fertility influenced intertemporal choices generally, we compared the baseline indifference points at peak and low fertility within subjects. Participants had mean indifference points of \$6.68 \pm 1.13 for peak fertility and \$6.34 \pm 1.31 for low fertility (see Figure 1a). This suggests no main effect of fertility state on baseline intertemporal choices (paired Wilcoxon signed-rank test, $V = 123$, $p = 0.51$).

To investigate whether Wilson and Daly’s (2004) “mating mindset” interacts with fertility state, we compared a difference score between pre- and post-exposure to the stimulus images, both with male and neutral images, and at peak and low fertility (see Figure 1b). We used the difference score as the dependent variable, the image type as a between-subjects factor, and fertility state as a within-subjects factor for a nonparametric analysis (Brunner, Domhof, and Langer, 2002). Though neither image type ($F_{(1,\infty)} = 0.49$, $p = 0.48$) or fertility status ($F_{(1,\infty)} = 0.08$, $p = 0.77$) influenced the difference score (no main effects), an image type by fertility status interaction occurred, $F_{(1,\infty)} = 5.81$, $p = 0.02$. A

nonparametric paired comparisons analysis for the interaction (Brunner et al., 2002) showed that, for women in the male image condition, viewing images increased choice for the larger, later option more at peak than low fertility ($L_{11} = 1.71$, $p = 0.04$, Glass's $\Delta = 0.69$). Thus, viewing attractive males reduced impulsivity at peak fertility compared to low fertility.

Figure 1. Intertemporal choices

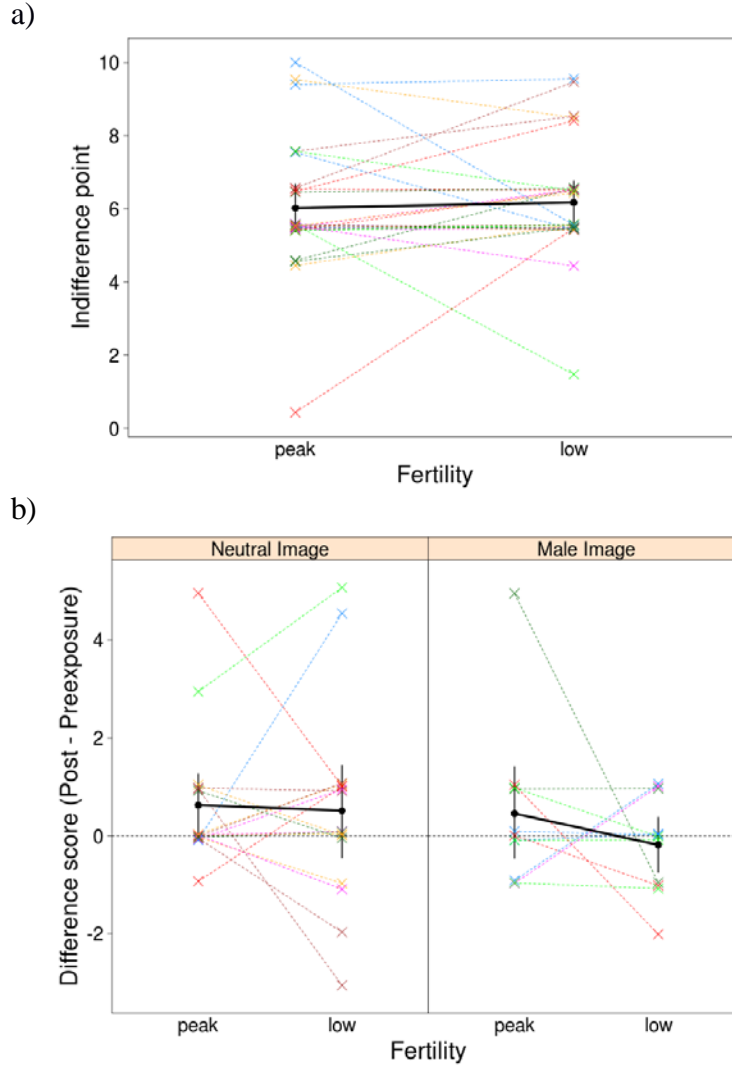


Notes: a) Indifference points represent the small amount received today that is equivalent to waiting 28 days for \$10. Values are from intertemporal choice tasks before exposure to male or neutral images for both peak and low fertility sessions for each participant. b) Difference scores are calculated as the difference between the post- and pre-exposure to male and neutral images. In the male image condition, women at peak fertility show higher indifference points than women at low fertility. Filled circles represent mean values, error bars represent bootstrapped 95% confidence intervals, and 'x's and lines represent individual participant data.

Risky choice

For baseline risky choice, participants had mean indifference points of 6.02 ± 0.66 for peak fertility and 6.18 ± 0.60 for low fertility (Figure 2a), suggesting no main effect of fertility state on baseline risky choices (Wilcoxon signed-rank test, $V = 55$, $p = 0.51$). Neither image type ($F_{(1,\infty)} = 0.71$, $p = 0.40$) nor fertility status ($F_{(1,\infty)} = 0.07$, $p = 0.79$) influenced the difference score, nor did an image type by fertility status interaction occur, $F_{(1,\infty)} = 0.53$, $p = 0.47$ (see Figure 2b).

Figure 2. Risky choices



Notes: a) Indifference points represent the chance (out of 10) of receiving \$16.69 that is equivalent to a 5/10 chance of \$18.33. Values are from risky choice tasks before exposure to male or neutral images for both peak and low fertility sessions for each participant. b) Difference scores are calculated as the difference between the post- and pre-exposure to male and neutral images. Filled circles represent mean values, error bars represent bootstrapped 95% confidence intervals, and \times 's and lines represent individual participant data.

Discussion

We observed no main effects of fertility status or image type on baseline intertemporal choice. Therefore, higher conception risk did not induce a general increase in impulsivity. We did find, however, a significant interaction between fertility status and image type on intertemporal choice. In particular, after viewing images of attractive men, women become less impulsive at peak fertility than at low fertility. We did not see any main effects of fertility or image type or an interaction in risky choice, so, in our monetary scenarios, we did not replicate the work suggesting that women become more risk seeking for gains at peak fertility.

Our overall hypothesis was that, compared to low fertility, women at peak fertility will make more impulsive and risky choices when primed for a “mating mindset” by viewing images of attractive men. Women in the male image condition were shown images of attractive men, making salient the availability of men of higher genetic quality in the mating market. Mating with men of higher genetic quality may result in offspring that possess similar traits, which increase reproductive success; thus, we expected women to increase their mating efforts around these hypothetical men when the chance of pregnancy was higher. Although we did find an interaction between image type and fertility status, the direction of the effect was the opposite of what we predicted. That is, being in a mating mindset made women less impulsive when at peak fertility compared to when at low fertility.

This finding may result from the possibility that mating opportunities at peak fertility trigger an emphasis on larger amounts of money, regardless of time delays. Additional money would afford women the opportunity to purchase items that enhance their desirability to potential mates. Data from risky choice, however, contradicts this hypothesis because peak fertility women did not preferentially choose the risky choice option with higher monetary outcomes following exposure to the images of attractive males. Yet, Figure 2b does show a pattern in the same direction as the intertemporal choice data. Given the small difference between the monetary options in the risky choice task (i.e., \$16.69 versus \$18.33), it is possible that larger differences in monetary amounts may also show that in the mating mindset, women at peak fertility prefer larger payoffs. Further replications of this task can test this possible explanation for the observed pattern of data.

The risky choice data did not replicate previous work showing a decrease or increase in risk taking at peak fertility (Bröder and Hohmann, 2003; Chavanne and Gallup, 1998; Pearson and Schipper, 2013). Our study differed from the previous work, however, in that the experiments demonstrating a reduction in risk taking at peak fertility primarily focused on sexual risk and avoiding rape. Research showing an increase in risk taking used an auction paradigm. The risky decisions were made in a social, competitive context in which women at peak fertility proposed lower bids (risking being outbid) than those at other points in their cycle. Although the current study was also in a monetary context, it did not involve the element of social uncertainty presented in the auction. In fact, our study tested risk (defined as a measurable source of variation with objective probabilities; e.g., a 5/10 chance of receiving \$10). This contrasts with the auction paradigm, which tests uncertainty (defined as an unmeasurable source of variation) in a social context, such as the

unknown bids of fellow auction participants. Previous research has demonstrated a difference in choices depending on whether variation results from risk or social uncertainty (Artinger, Fleischhut, Levanti, and Stevens, 2012). Thus, the very different source of risk in our study may trigger different decision mechanisms than those triggered in the previous studies.

Implications

The current research adds to the body of literature on adaptive decision making by testing intertemporal and risky decision making across the ovulatory cycle and in a mating domain. We argue that hormonal influences on behavior vary depending on the immediate social context. Though Wilson and Daly (2004) illustrated a clear effect of social context on men's intertemporal choices, the effect for women remained weaker. Our findings suggest that this may have resulted from their neglect of women's fertility status. Future research on human social behavior should continue to account for biological bases of behavior in an ecologically valid framework using more rigorous research methods.

Our results also suggest interesting implications about individual differences and measuring choice. Potential differences seen across individual female participants in intertemporal choice studies may reflect within-individual fluctuations over the ovulatory cycle rather than true between-individual differences, at least for cycling women. Thus, test-retest procedures (e.g., Kirby, 2009; Ohmura, Takahashi, Kitamura, and Wehr, 2006) should account for the cycle phase to ensure similar hormonal conditions across replications. Figures 1a and 2a demonstrate that women's choices vary dramatically (though not systematically) at different points in the cycle. Future work should more carefully track choice across more stages of the cycle and evaluate whether these fertility differences are consistent within individuals and across cycles. These differences across the cycle highlight a previously neglected source of variation for decision-making studies.

Similar to studies with human participants, research on animal decision making has often ignored the status of female cycling. We should now ask whether other species such as chimpanzees also show differences in intertemporal choices across their ovulatory cycle. Tracking cycling phase could be important for accounting for individual differences and measurement variation. This is particularly relevant for animal studies, since, unlike most human studies, animals are usually tested repeatedly over multiple weeks and use stability criteria. Different stability levels may be achieved at different points in the cycle for females. However, we may not expect changes across the cycle in all species. Species with reduced female choice may not show phase differences. In species in which there is little room for females to choose their mates, we would not predict more impulsive or risk-taking choices. Yet, females of species with more control over their mating partners may have evolved mating strategies that adaptively alter how they cope with time delays and risk across their ovulatory cycle. The evolutionary pressures of choosing a good mate have likely shaped critical decision-making mechanisms across a broad range of species.

Limitations

The major limitation of the current research is the small sample size. The within-subjects design of the study required women to participate twice: once at peak and once at

low fertility phases of the cycle. We lost a number of participants due to attrition and to the inability to detect peak fertility at mid-cycle. A larger sample may have allowed us to tease apart more subtle interaction effects between fertility status and mating context.

A second limitation is lack of control for additional individual differences. We have demonstrated individual differences not only in baseline impulsivity and risk taking (see Figures 1a and 2a) but also the effect of mating opportunities and fertility on these behaviors (see Figures 1b and 2b). Many interesting factors could underlie these differences. For example, individual differences in life history strategies of women, such as psychosocial stressors during development and subsequent timing of pubertal maturation (see Ellis, 2004, for review), may influence their decision making and approach to risk. Future research should build models that include not only the adaptive psychosocial contexts that affect behavior but also more stable dispositions.

Finally, we did not find an effect of fertility status on women's ratings of men's attractiveness. Previous research has documented women's increased attraction to masculine faces (Penton-Voak et al., 1999) and bodies (Little et al., 2007) in men at peak fertility phases of the cycle. We may not have been able to find an effect of fertility status on attractiveness ratings because the images were not pre-tested for masculinity or attractiveness by independent raters. Nevertheless, the attractiveness ratings measured in this study were comparable to those observed in Wilson and Daly (2004).

Conclusion

The current study builds on previous research on adaptations to the ovulatory cycle and adaptive accounts of intertemporal choice and risky decision making. This study tested interactions between human females' fertility status and adaptive contexts to predict their intertemporal choices and risky decision making. The results of this research encourage future empirical studies built on larger sample sizes to further explore adaptations that shift women's decision making across the ovulatory cycle.

Acknowledgements: The manuscript for this study was prepared while Dr. Kaighobadi was at the HIV Center for Clinical and Behavioral Studies at Columbia University and New York State Psychiatric Institute, where she was supported by Award Number T32 MH019139 (Principal Investigator, Theodorus Sandfort, Ph.D.), from the National Institute of Mental Health. The content is solely the responsibility of the authors and does not necessarily represent the official views of National Institute of Mental Health or the National Institutes of Health. We thank Uwe Czienskowski for developing the Disc'n'Risk program and Cassandra de Paula Silva and Diana M. Lopez for their help in data collection and entry. We also thank the Department of Psychology at Florida Atlantic University and Professor Todd K. Shackelford for supporting Farnaz Kaighobadi to conduct this research. This project was funded by the Max Planck Institute for Human Development.

Received 02 September 2012; Revision submitted 04 December 2012; Accepted 04 December 2012

References

- Artinger, F., Fleischhut, N., Levanti, V., and Stevens, J. R. (2012). Cooperation in risky environments: Decisions from experience in a stochastic social dilemma. *Proceedings of the 34th Conference of the Cognitive Science Society* (pp. 84-89). Sapporo, Japan: Cognitive Science Society.
- Ayduk, O., Mendoza-Denton, R., Mischel, W., Downey, G., Peake, P. K., and Rodriguez, M. (2000). Regulating the interpersonal self: Strategic self-regulation for coping with rejection sensitivity. *Journal of Personality and Social Psychology*, *79*, 776-792.
- Bröder, A., and Hohmann, N. (2003). Variations in risk-taking behavior over the menstrual cycle: An improved replication. *Evolution and Human Behavior*, *24*, 391-398.
- Brunner, E., Domhof, S., and Langer, F. (2002). *Nonparametric analysis of longitudinal data in factorial experiments*. New York: J. Wiley.
- Bullivant, S. B., Sellergren, S. A., Stern, K., Spencer, N. A., Jacob, S., Mennella, J. A., and McClintock, M. K. (2004). Women's sexual experiences during the menstrual cycle: Identification of the sexual phase by noninvasive measurement of luteinizing hormone. *Journal of Sex Research*, *41*, 82-93.
- Canty, A., and Ripley, B. (2012). *boot: Bootstrap R (S-Plus) Functions*. (R version 1.3-7).
- Caraco, T., Martindale, S., and Whittam, T. S. (1980). An empirical demonstration of risk-sensitive foraging preferences. *Animal Behaviour*, *28*, 820-830.
- Chavanne, T. J., and Gallup, G. G. (1998). Variation in risk taking behavior among female college students as a function of the menstrual cycle. *Evolution and Human Behavior*, *19*, 27-32.
- Chongsuvivatwong, V. (2012). *epicalc: Epidemiological calculator*. (R version 2.15.1.0).
- Duckworth, A. L., and Seligman, M. E. P. (2005). Self-discipline outdoes IQ in predicting academic performance of adolescents. *Psychological Science*, *16*, 939-944.
- Durante, K. M., Griskevicius, V., Hill, S. E., Perilloux, C., and Li, N. P. (2011). Ovulation, female competition, and product choice: Hormonal influences on consumer behavior. *Journal of Consumer Research*, *37*, 921-934.
- Ellis, B. J. (2004). Timing of pubertal maturation in girls: An integrated life history approach. *Psychological Bulletin*, *130*, 920-958.
- Fawcett, T. W., McNamara, J. M., and Houston, A. I. (2012). When is it adaptive to be patient? A general framework for evaluating delayed rewards. *Behavioural Processes*, *89*, 128-136.
- Feinberg, D. R., Jones, B. C., Law Smith, M. J., Moore, F. R., DeBruine, L. M., Cornwell, R. E., . . . Perrett, D. I. (2006). Menstrual cycle, trait estrogen level and masculinity preferences in the human voice. *Hormones and Behavior*, *49*, 215-233.
- Gangestad, S. W., Garver-Apgar, C. E., Simpson, J. A., and Cousins, A. J. (2007). Changes in women's mate preferences across the ovulatory cycle. *Journal of Personality and Social Psychology*, *92*, 151-163.
- Gangestad, S. W., and Thornhill, R. (1998). Menstrual cycle variations in women's

- preference for the scent of symmetrical men. *Proceedings of the Royal Society B*, 265, 927-933.
- Gangestad, S. W., Thornhill, R., and Garver-Apgar, C. E. (2005a). Adaptations to ovulation: Implications for sexual and social behavior. *Current Directions in Psychological Science*, 14, 312-316.
- Gangestad, S. W., Thornhill, R., and Garver-Apgar, C. E. (2005b). Women's sexual interests across the ovulatory cycle depend on primary partner fluctuating asymmetry. *Proceedings of the Royal Society B*, 272, 203-2027.
- Gilby, I. C., and Wrangham, R. W. (2007). Risk-prone hunting by chimpanzees (*Pan troglodytes schweinfurthii*) increases during periods of high diet quality. *Behavioral Ecology and Sociobiology*, 61, 1771-1779.
- Hammerstein, P., and Stevens, J. R. (Eds.) (2012). *Evolution and the mechanisms of decision making*. Cambridge, MA: MIT Press.
- Harrell, F. E., and with contributions from many other users. (2012). *Hmisc: Harrell miscellaneous*. (R version 3.10-1).
- Haselton, M. G., and Gangestad, S. W. (2006). Conditional expression of women's desires and men's mate retention across the ovulatory cycle. *Hormones and Behavior*, 49, 509-518.
- Haselton, M. G., Mortezaie, M., Pillsworth, E. G., Bleske-Rechek, A., and Fredrick, D. A. (2007). Ovulatory shifts in human female ornamentation: Near ovulation, women dress to impress. *Hormones and Behavior*, 51, 40-45.
- Haun, D. B. M., Nawroth, C., and Call, J. (2011). Great apes' risk-taking strategies in a decision making task. *PLoS ONE*, 6, e28801.
- Heilbrunner, S. R., Rosati, A. G., Stevens, J. R., Hare, B., and Hauser, M. D. (2008). A fruit in the hand or two in the bush? Divergent risk preferences in chimpanzees and bonobos. *Biology Letters*, 4, 246-249.
- Kacelnik, A., and Bateson, M. (1996). Risky theories: The effects of variance on foraging decisions. *American Zoologist*, 36, 402-434.
- Kirby, K. N. (2009). One-year temporal stability of delay-discount rates. *Psychonomic Bulletin and Review*, 16, 457-462.
- Krupp, D. B., DeBruine, L. M., and Barclay, P. (2008). A cue of kinship promotes cooperation for the public good. *Evolution and Human Behavior*, 29, 49-55.
- Little, A. C., Jones, B. C., and Burriss, R. P. (2007). Preferences for masculinity in male bodies change across the menstrual cycle. *Hormones and Behavior*, 51, 633-639.
- Mischel, W., Shoda, Y., and Rodriguez, M. L. (1989). Delay of gratification in children. *Science*, 244, 933-938.
- Noguchi, K., Gel, Y. R., Brunner, E., and Konietzschke, F. (2012). nparLD: An R software package for the nonparametric analysis of longitudinal data in factorial experiments. *Journal of Statistical Software*, 50, 1-23.
- Ohmura, Y., Takahashi, T., Kitamura, N., and Wehr, P. (2006). Three-month stability of delay and probability discounting measures. *Experimental and Clinical Psychopharmacology*, 14, 318-328.
- Pearson, M., and Schipper, B. C. (2013). Menstrual cycle and competitive bidding. *Games and Economic Behavior*, 78, 1-20.

- Penton-Voak, I. S., Perrett, D. I., Castles, D. L., Kobayashi, T., Burt, D. M., Murray, L. K., and Minamisawa, R. (1999). Menstrual cycle alters face preference. *Nature*, 399, 741-742.
- R Development Core Team. (2012). *R: A language and environment for statistical computing*. Vienna: R Foundation for Statistical Computing.
- Read, D. (2004). Intertemporal choice. In D. Koehler and N. Harvey (Eds.), *Blackwell handbook of judgment and decision making* (pp. 424-443). Oxford, UK: Blackwell.
- Roitberg, B. D., Sircom, J., Roitberg, C. A., van Alphen, J. J. M., and Mangel, M. (1993). Life expectancy and reproduction. *Nature*, 364, 108-108.
- Roney, J. R., and Simmons, Z. L. (2008). Women's estradiol predicts preference for facial cues of men's testosterone. *Hormones and Behavior*, 53, 14-19.
- Rosati, A. G., and Hare, B. (2011). Chimpanzees and bonobos distinguish between risk and ambiguity. *Biology Letters*, 7, 15-18.
- Rosati, A. G., and Hare, B. (2012). Decision making across social contexts: Competition increases preferences for risk in chimpanzees and bonobos. *Animal Behaviour*, 84, 869-879.
- Rosati, A. G., Stevens, J. R., Hare, B., and Hauser, M. D. (2007). The evolutionary origins of human patience: Temporal preferences in chimpanzees, bonobos, and adult humans. *Current Biology*, 17, 1663-1668.
- Sarkar, D. (2008). *Lattice: Multivariate data visualization with R*. New York: Springer.
- Sarkar, D., and Andrews, F. (2011). *latticeExtra: Extra graphical utilities based on Lattice*. (R version 0.6-24).
- Smith, F. G., DeBruine, L. M., Jones, B. C., Krupp, D. B., Welling, L. L. M., and Conway, C. A. (2009). Attractiveness qualifies the effect of observation on trusting behavior in an economic game. *Evolution and Human Behavior*, 30, 393-397.
- Snowdon, C. T., and Soini, P. (1988). The tamarins, genus *Saguinus*. In R. A. Mittermeier, A. B. Rylands, A. F. Coimbra-Filho, and G. A. B. Fonseca (Eds.), *Ecology and behavior of Neotropical primates (Vol. 2)* (pp. 223-298). Washington, DC: World Wildlife Fund.
- Stanford, C. B. (1998). The social behavior of chimpanzees and bonobos: Empirical evidence and shifting assumptions. *Current Anthropology*, 39, 399-420.
- Stephens, D. W. (1981). The logic of risk-sensitive foraging preferences. *Animal Behaviour*, 29, 628-629.
- Stephens, D. W., and Krebs, J. R. (1986). *Foraging theory*. Princeton: Princeton University Press.
- Stevens, J. R. (2010a). Rational decision making in primates: The bounded and the ecological. In M. L. Platt and A. Ghazanfar (Eds.), *Primate neuroethology* (pp. 98-116). Oxford: Oxford University Press.
- Stevens, J. R. (2010b). Intertemporal choice. In M. D. Breed and J. Moore (Eds.), *Encyclopedia of animal behavior (Vol. 2)* (pp. 203-208). Oxford: Academic Press.
- Stevens, J. R., Hallinan, E. V., and Hauser, M. D. (2005). The ecology and evolution of patience in two New World monkeys. *Biology Letters*, 1, 223-226.
- Stevens, J. R., and Stephens, D. W. (2009). The adaptive nature of impulsivity. In G. J. Madden and W. K. Bickel (Eds.), *Impulsivity: The behavioral and neurological*

- science of discounting* (pp. 361-387). Washington, DC: American Psychological Association.
- Stevenson, M. F., and Rylands, A. B. (1988). The marmosets, genus *Callithrix*. In R. A. Mittermeier, A. B. Rylands, A. F. Coimbra-Filho, and G. A. B. Fonseca (Eds.), *Ecology and behavior of Neotropical primates (Vol. 2)* (pp. 131-222). Washington, DC: World Wildlife Fund.
- Wilson, M., and Daly, M. (2004). Do pretty women inspire men to discount future? *Proceedings of the Royal Society B*, 271 (Suppl. 4), S177-179.
- Wood, D., and Brumbaugh, C. (2009). Using revealed mate preferences to evaluate market force and differential preference explanations for mate selection. *Journal of Personality and Social Psychology*, 96, 1226-1244.
- Wrangham, R. W., and Pilbeam, D. (2002). African apes as time machines. In B. M. F. Galdikas, N. E. Briggs, L. K. Sheeran, G. L. Shapiro, and J. Goodall (Eds.), *All apes great and small (Vol. 1, African Apes)* (pp. 5-17). New York: Plenum/Kluwer.
- Wu, G., Zhang, J., and Gonzalez, R. (2004). Decision under risk. In D. Koehler and N. Harvey (Eds.), *Blackwell handbook of judgment and decision making* (pp. 399-423). Oxford: Blackwell.