

Schipper, Burkhard C.

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## DEPARTMENT OF ECONOMICS

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Sex Hormones and Choice under Risk

Burkhard Schipper  
University of California, Davis

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Department of Economics  
One Shields Avenue  
Davis, CA 95616  
(530)752-0741

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# SEX HORMONES AND CHOICE UNDER RISK\*

Burkhard C. Schipper<sup>†</sup>

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## Abstract

We correlate choice under risk in Holt-Laury lottery tasks for gains and losses with salivary testosterone, estradiol, progesterone, and cortisol, the use of hormonal contraceptives, menstrual cycle information as well as the digit ratio (2D:4D) in more than 200 subjects. Risk aversion is negatively correlated with testosterone and positively correlated with cortisol, a stress hormone, for gains only. In males, testosterone is negatively correlated with risk aversion for gains only. In females, cortisol is marginally significantly positively correlated with risk aversion for gains only. No other significant correlations between risk aversion and salivary hormones are observed. In females, testosterone and progesterone are positively correlated with reflection, i.e., risk aversion for gains and risk seeking for losses. Testosterone is negatively correlated with “consistency” of preferences in females, while estradiol is negatively correlated with “consistency” of preferences in males. No significant correlations between risk aversion and the menstrual cycle or the digit ratio are observed. Females on hormonal contraceptives are more likely to make “consistent” choices although this may be due to a selection effect. Risk aversion is positively correlated with being female for losses only. Yet, if we control for salivary hormones we are surprised to find a negative correlation between female and risk aversion for gains.

**Keywords:** Hormones, Menstrual cycle, Contraception, Digit ratio, 2D:4D, Gender, Risk behavior, Endocrinological economics, Holt-Laury, Risk aversion, Risk seeking, Reflection effect, Prospect theory.

**JEL-Classifications:** C91, C92, D44, D81, D87.

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<sup>†</sup>Department of Economics, University of California, Davis. Email: bcschipper@ucdavis.edu

# 1 Introduction

Gender differences continue to puzzle economists and policy makers in a number of economically relevant domains including investment (e.g. Barber and Odean, 2001) and the labor market (see Blau and Kahn, 2000, for a review). There is a sizeable literature that attempts to trace those gender differences back to differences in preferences between men and women such as risk preferences, social preferences, and preferences for competition (see Croson and Gneezy, 2009, Eckel and Grossman, 2008a, b, Byrnes, Miller, and Schafer, 1999, and Niederle and Vesterlund, 2011, for surveys). In this article we will focus on risk preferences. Croson and Gneezy (2009, p. 2) claim that “(t)he robust finding is that men are more risk-prone than are women.” Similarly, Eckel and Grossman (2008a) state that “in most studies, women are found to be more averse to risk than men. Studies with contextual frames show less consistent results.” Croson and Gneezy (2009, pp. 4-6) consider emotions, overconfidence, and challenges/threats as reasons for gender differences in risk-taking. In this paper we are interested in biological factors that may shape these gender differences in risk preferences. In particular, we focus on endocrinological factors. Men and women differ in circulating levels of sex steroid hormones such as testosterone and progesterone. Such differences are not surprising since natural sex steroids are produced by endocrinal glands such as the ovaries, testis, adrenal glands etc. We are not only interested to what extent sex hormones are correlated with differences in risk behavior between sexes but also within sexes. Can sex hormones explain all, some or none of the gender differences in risk-taking? Is risk-taking correlated with the same hormones (if any) in both men and women? Do different hormones play a role for risk-taking in the gain domain versus the loss domain? Are correlations between salivary hormones and risk preferences robust to controlling for demographics, variables that affect the quality of salivary hormone measurements etc.? Besides the typical sex hormones testosterone, estradiol, and progesterone, we also measure cortisol in saliva. Since cortisol is considered a “stress hormone”, it is naturally related to risk-taking.

Some hormones may follow cycles. For instance, estradiol and progesterone vary across the menstrual cycle (see Figure 8) in naturally cycling women, i.e., women who do not use hormonal contraceptives (see for instance, Chatterton et al., 2005). If risk-taking varies systematically for those hormones, then we may be able to see changes in risk-taking across the cycle. To investigate this hypothesis, we collect self-reported information on women’s menstrual cycle as well as the use of hormonal contraceptives.

Behavior may not just be affected by current hormones levels but also by prenatal exposure to certain hormones. That is, we are interested in what sense risk-taking may be influenced by biological events before birth. We use as a proxy the “visible hand,” that is the ratio between the length of the 2nd (index) finger and the 4th (ring) finger of the subjects’ right hand (so called “digit ratio” or 2D:4D). (See Manning, 2002, for an introduction.) 2D:4D is positively correlated with prenatal exposure to estrogen and negatively correlated to prenatal exposure to testosterone (Manning et al., 1998, Lutchmaya et al., 2004, Hönekopp et al., 2007). On average, men have lower 2D:4D than women. 2D:4D is to a large extent genetically determined (Paul et al., 2006), but

it may also be affected by the environment *in utero*. In any case, 2D:4D is determined before birth and thus before common economic, social, and cultural factors could shape risk-taking behavior of the individual directly.

We measure risk preferences using a lottery choice task due to Holt and Laury (2002), which consists of presenting each subject of our experiment with a list of pairs of lotteries. The subject has to make a choice between the lotteries for each pair of lotteries in the list (see Section 2.1). The probability of outcomes varies systematically across the list of lottery pairs. While this design has been originally applied to lotteries involving monetary gains only, Laury and Holt (2008) extend it also to lotteries involving monetary losses. This allows them to study postulates of prospect theory (see Kahneman and Tversky, 1979, and Tversky and Kahneman, 1992) such as the reflection effect, i.e., risk aversion for gains and risk seeking for losses.<sup>1</sup>

While we do not know of any other study that investigates the correlation between choice under risk for *both gains and losses* and *all of salivary testosterone, estradiol, progesterone, and cortisol*, we are not the first to study the correlation between salivary testosterone and risk aversion. Apicella et al. (2008) find that risk-taking in an investment task is significantly positively correlated with salivary testosterone levels in men. They use an investment task adapted from Gneezy and Potters (1997). Each participant was asked to allocate an amount  $x \in [\$0, \$250]$  to a risky investment with the remainder of the \$250 initial balance retained by the participant. A coin flip determined the success of the investment in which case the money invested was multiplied by 2.5. Otherwise, the investment was lost. At the end of the experiment, one of the 98 male participants was selected randomly and paid accordingly. Testosterone levels were measured from saliva by passive drool. Our study differs from Apicella et al. (2008) in several respects. First, instead of the Gneezy and Potters (1997) investment decision task, we use the Holt-Laury lottery tasks for both gains and losses. This allows us to study how risk preferences may differ between the gain and loss domains including the reflection effect, and how any such differences are correlated with sex hormones. Moreover, we can also observe “inconsistencies” in choice behavior and their correlation with gender and salivary hormones. Second, different from Apicella et al. (2008) we study both males and females. Third, besides salivary testosterone we also collect measures of salivary estradiol, progesterone, and cortisol. With respect to salivary testosterone and risk-taking by males in the gain domain, we are able to replicate the conclusion of Apicella et al. (2008) with our different choice task. But we also show that the positive correlation between salivary testosterone and risk-taking does not extend to losses and to females.

Our findings and the findings by Apicella et al. (2008) are somewhat in contrast to results by Sapienza et al. (2009). They collect data on choice under risk using a Holt-Laury lottery task for gains only. Sapienza et al. (2009) find in their relative large sample of 550 MBA students a significant negative correlation between salivary

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<sup>1</sup>See Harrison and Ruthström (2008) for a survey on experiments on risk preferences. They compare various methods to elicit risk preferences including Holt-Laury lottery tasks. Moreover, they discuss further experimental evidence gathered with Holt-Laury lottery tasks.

testosterone concentrations and risk aversion that becomes insignificant when controlling for gender. When data were analyzed separately by gender, they find only a weak insignificant negative relationship between risk aversion and testosterone in males but a stronger and statistically significant negative relationship in females.

Our study relates more generally to the small but growing literature that seeks to correlate economically relevant behavior with direct measurements of circulating hormones. Burnham (2007) shows that men with high salivary testosterone are more likely to reject low offers in an ultimatum bargaining game. Sanchez-Pages and Turiegano (2011) found no correlation of salivary testosterone and cooperation in a one-shot prisoners' dilemma. Zak, Kurzban, and Matzner (2005) report that blood plasma levels of oxytocin are positively correlated with trustworthy behavior in a trust game. Zak, Kurzban, and Matzner (2004) mention that ovulating women are also statistically less trustworthy, where ovulation is established with a progesterone-based indicator from blood plasma. Johnson et al. (2006) find no evidence that subjects with higher levels of salivary testosterone were more likely to make unprovoked attacks in a war game. Using the same sample as in the current paper, Schipper (2012) reports that in sealed-bid symmetric independent private value first-price auctions, bidding is significantly positively correlated with salivary progesterone and profits are significantly negatively correlated with salivary progesterone. No such correlations are observed for salivary testosterone, estradiol, or cortisol. Together with the results in the current paper it suggests that bidding above risk-neutral Nash equilibrium may not be due to risk-aversion in first-price auctions with symmetric independent private values. Outside the lab, Coates and Herbert (2008) show that salivary morning testosterone levels are positively correlated with daily profits in 17 male financial traders in the City of London studied over 8 days. They also show that a trader's salivary cortisol level rises with both the variance of his trading results and the volatility of the market.

There is also a related literature on economic experiments using placebo-controlled administration of hormones. Using a sample of 200 healthy post-menopausal women, Zethraeus et al. (2009) did not find a correlation between randomly administered testosterone or estrogen and risk-taking. Kosfeld et al. (2005) show that intranasal administration of oxytocin slightly increases giving in a trust game but it does not increase trustworthiness and it does not generally increase risk-taking. (See also Baumgartner et al., 2008). Zak, Stanton, and Ahmadi (2007) show that subjects infused with oxytocin give more in an ultimatum bargaining game but not in a dictator game as compared to a placebo. Zak et al. (2009) show that applying a testosterone gel to men decreases giving in an ultimatum bargaining game and increases spiteful behavior towards ungenerous proposers. Yet, for women, Eisenegger et al. (2010) show that sublingual administration of testosterone to women increases offers in an ultimatum bargaining game unless they believed that they received testosterone. It should be pointed out though that to further our understanding of how hormones effect economic behavior it requires both careful correlation studies and placebo-controlled experiments. In order to establish causalities with placebo-controlled studies, it is necessary to know whether exogenous administered hormones act actually similar to endogenous hormones, establish knowledge about doses administered and effect size and its relation to endogenous levels, as well as elaborate the

interaction between exogenous and endogenous hormones. For most hormones of interest to behavioral studies, this knowledge is extremely preliminary.

Our study is not the first one investigating the relation between self-reported menstrual cycle information, the use of hormonal contraceptives, and economic behavior. Chen, Katuščák, and Ozdenoren (2009) report that women bid higher than men in all phases of their menstrual cycle in a symmetric independent private value first-price auction but not in a second-price auction. Moreover, for first-price auctions they infer that higher bidding in the follicular phase and lower bidding in the luteal phase are driven entirely by oral hormonal contraceptives. This is somewhat in contrast to Pearson and Schipper (2011) who, using a subsample of the current study, find that naturally cycling women bid significantly higher than men and earn significantly lower profits than men in first-price auctions with symmetric independent private values except during the midcycle when fecundity is highest. Higher bidding of women may be due to risk aversion but risk aversion is behaviorally indistinguishable in these auctions from other attitudes such as relative payoff concerns (Morgan et al., 2003), anticipated loser regret (Filiz and Ozbay, 2007), the joy of winning, etc. They suggest an evolutionary hypothesis according to which women are predisposed by hormones to generally behave more risky during their fecund phase of their menstrual cycle in order to increase the probability of conception, quality of offspring, and genetic variety. They also find that women on hormonal contraceptives bid significantly higher and earn substantially lower profits than men. Wozniak, Harbaugh, and Mayr (2010) study the correlation between the selection into tournaments with either piece-rate and winner-take-all compensation à la Gneezy, Niederle, and Rustichini (2003) and Niederle and Vesterlund (2007) and the menstrual cycle. They find that women early in their menstrual cycle are relatively more reluctant to choose winner-take-all compensation than women later in their menstrual cycle. No such differences (also no differences between men and women) are observed when participants receive feedback about their relative performance. In an all-female sample, Buser (2012a) comes to a different conclusion. He observes that women later in their menstrual cycle are relatively more reluctant to choose winner-take-all compensation. Buser (2012a) also includes tasks for choice under risk using both an Eckel and Grossman (2002) lottery choice task and a Holt-Laury lottery choice task for gains. For the Eckel-Grossman task he reports for his sample of 54 naturally cycling women and 52 women on hormonal contraceptives that neither menstrual cycle phase nor hormonal contraceptives have a significant effect on risk aversion. He also mentions (Buser, 2012a, Fn. 6) that his conclusions do not change if Holt-Laury task were considered instead. Buser (2012b) studies the correlation between social preferences and self-reported menstrual cycle information. Women give significantly less than men in a trust game but not during the midcycle. Moreover, women are more likely than men to pick equal allocations in a dictator game in the luteal phase only and return a higher proportion than men in the trust game during the luteal phase only. Women also offer significantly more than men in an ultimatum bargaining game during the midcycle only and reject offers significantly less often during the midcycle only. Finally, women contribute significantly more than men to a public good during

menstruation.<sup>2</sup>

Our investigation is directly related to previous studies of the prenatal exposure to sex hormones that employed the digit ratio (2D:4D). Dreber and Hoffman (2007) and Garbarino et al. (2011) show that risk-taking in investment tasks are significantly negatively correlated with 2D:4D in white subjects but Apicella et al. (2008) show that this is not the case in a more racially mixed male sample. Sapienza et al. (2009) do not find a significant correlation between risk aversion and 2D:4D in a lottery choice task except for a marginal significant positive correlation for females in a sample of 550 MBA students.<sup>3</sup> Both Dreber and Hoffman (2007) and Apicella et al. (2008) use the investment task adapted from Gneezy and Potters (1997) while we use the lottery choice task for gains and losses of Holt and Laury (2002) and Laury and Holt (2008). Sapienza et al. (2009) also uses a Holt-Laury lottery task but they confine themselves to gains only. Garbarino et al. (2011) employ ordered lottery sequences adapted from Eckel and Grossman (2002, 2008c) for gains, losses, and mixed gains and losses. Brañas Garza and Rustichini (2011) study the correlation between 2D:4D, risk aversion, and abstract reasoning ability. They employ two measures of risk aversion in a sample of 188 Caucasian subjects. One of measures is derived from choices in a Holt-Laury lottery task. For this measure they report a significant but negative correlation between the digit ratio and risk aversion for females (for the other measure it is insignificant). For males they report a nonsignificant positive correlation between risk aversion and the digit ratio (for the other measure it is significant). They also study how prenatal hormone exposure may affect risk aversion indirectly through abstract reasoning ability. With respect to this literature on the digit ratio and risk aversion, we essentially replicate the null-results by Apicella et al. (2008) with a different task for choice under risk. But we also show that the null result extends to females and to choice under risk in the loss domain.<sup>4</sup>

More generally, our study relates to the literature on the correlation between the digit ratio and economic behavior. Coates, Gurnell, and Rustichini (2009) find that lower 2D:4D predicts the 20-month average profitability of 44 male high-frequency traders in London. In a companion paper using a supersample of the current paper, Pearson and Schipper (2012) do not find a significant correlation of both competitive bidding and

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<sup>2</sup>The effect of the menstrual cycle on labor market outcomes has been studied directly in the labor market. Using data from a large Italian bank, Ichino and Moretti (2008) conclude that the women's higher levels of absenteeism in the workplace due to their menstrual cycle explains at least 14% of the gender wage gap. But Rockoff and Hermann (2012) do not find that absenteeism is due to the menstrual cycle for a data set of teachers and show that the result by Ichino and Moretti (2008) is not robust to the correction of coding errors.

<sup>3</sup>Using a questionnaire on various domains of risk, Stenstrom et al. (2011) find a marginally significant negative correlation between financial risk taking and digit ratio in males but only null results for recreational, social, ethical, or health risks or females. When we consider multiple testing, we must interpret their finding as null result.

<sup>4</sup>Apicella et al. (2008) also collect information on facial symmetry, a measure of pubertal hormone exposure. They find that risk-taking in an investment game correlates significantly positively with facial masculinity.



profits with 2D:4D in sealed-bid symmetric independent private value first-price auctions. This may be due to their racially mixed sample. Van den Bergh and Dewitte (2006) report that in ultimatum bargaining games men with lower 2D:4D are more likely to reject unfair offers in neutral contexts but are more likely to accept unfair offers in sex-related contexts. Using a public good game, Millet and Dewitte (2006) find that men and women with lower digit ratios contribute proportionally, whereas those with higher 2D:4D contributed either more or less. Sanchez-Pages and Turiegano (2011) show that men with intermediate 2D:4D are more likely to cooperate in a one-shot prisoners’ dilemma game. Finally, using a large survey of entrepreneurs in Italy, Guiso and Rustichini (2011) show that the digit ratio of entrepreneurs is negatively correlated the size of the firms.

Our study can be seen as a part of a larger recent research program that may be termed “endocrinological economics”. It is known that various hormones regulate behavior to some extent (Nelson, 2011). To better understand human nature with regard to economic activities, it may be of interest to investigate to what extent hormones may effect economic behavior.

The paper is organized as follows: Section 2 outlines the experimental design. The results are reported in Section 3, where we also present some robustness checks. The Appendix contains the further details on the salivary hormone methodology, instructions, screen shots, and the questionnaire. Different to most research in this area, the data and Stata do-file that reproduces the entire analysis reported here and more are available from <http://www.econ.ucdavis.edu/faculty/schipper/>.

## 2 Experimental Design

### 2.1 Holt-Laury Lottery Tasks

We study choice under risk using lottery choice tasks introduced by Holt and Laury (2002) for the gain domain and Laury and Holt (2008) for the loss domain. Each lottery choice task consists of a menu of 10 decisions between pairs of lotteries. Table 1 shows the lottery choices for the loss domain. The first column numbers the decisions. The second and third columns present the pairs of lotteries, named “option A” and “option B”, respectively. For each of the 10 choices, each subject had to decide between option A and B, and indicate it in the fourth column. The fifth and last column is not shown to subjects in the experiment but printed here for convenience of the reader. It shows for each decision the difference of the expected payoffs between options A and B.

In Decision No. 1, the choice is between a loss of \$3.20 (option A) and a loss of \$0.20 (option B). A subject respecting dominance should chose option B. Observe that the two payoffs for lotteries under option A have roughly the same magnitude. Thus, this lottery is relatively “safe”. The lower the decision in Table 1, the higher becomes the probability for the worse outcome -\$4.00 for option A and -\$7.70 for option B. The optimal choice of a risk neutral individual is to choose option B for the first five decisions and then switch

Table 1: Holt-Laury Lottery Task for the Loss Domain

| Decision No. | Option A  | Option B  | Your Choice | Exp. Payoff A - Exp. Payoff B (not shown) |
|--------------|---|---|-------------|---|
| 1            | -\$3.20 if throw of die is 1 to 10                                      | -\$0.20 if throw of die is 1 to 10                                      |             | -\$3.00                                   |
| 2            | -\$4.00 if throw of die is 1<br>-\$3.20 if throw of die is 2 to 10      | -\$7.70 if throw of die is 1<br>-\$0.20 if throw of die is 2 to 10      |             | -\$2.33                                   |
| 3            | -\$4.00 if throw of die is 1 or 2<br>-\$3.20 if throw of die is 3 to 10 | -\$7.70 if throw of die is 1 or 2<br>-\$0.20 if throw of die is 3 to 10 |             | -\$1.66                                   |
| 4            | -\$4.00 if throw of die is 1 to 3<br>-\$3.20 if throw of die is 4 to 10 | -\$7.70 if throw of die is 1 to 3<br>-\$0.20 if throw of die is 4 to 10 |             | -\$0.99                                   |
| 5            | -\$4.00 if throw of die is 1 to 4<br>-\$3.20 if throw of die is 5 to 10 | -\$7.70 if throw of die is 1 to 4<br>-\$0.20 if throw of die is 5 to 10 |             | -\$0.32                                   |
| 6            | -\$4.00 if throw of die is 1 to 5<br>-\$3.20 if throw of die is 6 to 10 | -\$7.70 if throw of die is 1 to 5<br>-\$0.20 if throw of die is 6 to 10 |             | \$0.35                                    |
| 7            | -\$4.00 if throw of die is 1 to 6<br>-\$3.20 if throw of die is 7 to 10 | -\$7.70 if throw of die is 1 to 6<br>-\$0.20 if throw of die is 7 to 10 |             | \$1.02                                    |
| 8            | -\$4.00 if throw of die is 1 to 7<br>-\$3.20 if throw of die is 8 to 10 | -\$7.70 if throw of die is 1 to 7<br>-\$0.20 if throw of die is 8 to 10 |             | \$1.69                                    |
| 9            | -\$4.00 if throw of die is 1 to 8<br>-\$3.20 if throw of die is 9 or 10 | -\$7.70 if throw of die is 1 to 8<br>-\$0.20 if throw of die is 9 or 10 |             | \$2.36                                    |
| 10           | -\$4.00 if throw of die is 1 to 9<br>-\$3.20 if throw of die is 10      | -\$7.70 if throw of die is 1 to 9<br>-\$0.20 if throw of die is 10      |             | \$3.03                                    |

to option A for decisions 6 to 10 as the expected value is higher for B than A in the first five decisions, while the expected value for A is higher than B for decisions 6 to 10 (see last column). A sufficiently risk averse individual tends to switch to option A before Decision No. 6, while a sufficiently risk seeking individual switches to option A after

Decision No. 6.

The lottery choice task for the gain domain is analogous to Table 1 except that losses are replaced with corresponding gains (see Appendix B) and thus the signs of differences in expected payoffs of the last column are reversed. A risk neutral individual will start out in Decision No. 1 with option A and switch to option B from Decision No. 6 onward. A sufficiently risk averse individual will switch to option B after choosing option A for more than the first five decisions, while a sufficiently risk seeking individual will switch to option B before Decision No. 6.

In both, the loss and gain domains, risk neutrality implies choosing option A five times, sufficient risk aversion implies choosing option A more than five times, while sufficient risk seeking implies choosing option A less than five times. Thus as a matter of terminology, we say that an individual is *risk averse* if she chooses option A more than five times, *risk neutral* if she chooses option A exactly five times, and *risk seeking* if she chooses option A less than five times. We say that a group X of subjects is *more risk averse* (resp. *more risk seeking*) than a group Y if on average it chooses option A more often (resp. less often) than group Y.

It is possible to fit for each domain and for each number of “consistent” choices of option A the corresponding interval of risk parameters for popular utility functions such as constant relative risk aversion (see Holt and Laury, 2002, Laury and Holt, 2008, Harrison and Ruthström, 2008). But we believe that in this study it adds nothing beyond our behavioral definitions of risk aversion and risk seeking behavior above.

Kahneman and Tversky (1979) and Tversky and Kahneman (1992) observed that frequently individuals are risk averse in the gain domain while risk seeking in the loss domain. A subject is said to show the *reflection* effect if she is risk averse in the gain domain and risk seeking in the loss domain, i.e., if she chooses option A more than five times in gain domain and less than five times in the loss domain.

Not all subjects may display a unique cut-off for switching between the options but may switch several times between options A and B. Moreover, a subject may not respect dominance and thus may not choose option A and B in Decision No. 1 in the gain and loss domain, respectively. If we observe a subject switching several times, we should not dismiss the preferences too quickly as being “inconsistent”. We simply don’t know why it switches several times. It could be that the subject is just indifferent and that’s why when forced to make a choice may switch between options several times. It could also be that the subject is not indifferent but simply makes a mistake in writing down the wrong choice. Finally, it could be that the subject “happily violates” the assumption of maximizing expected monetary payoffs. In any case, the information obtained from subjects who switch several times or choose the dominated option is limited. That’s why we call a subject’s preference *accessible* if the subject has a unique cut-off for switching between options and respects dominance. Otherwise, we call the subject *inaccessible*.

Appendix C contains the instructions for the lottery task provided to subjects of our experiment.

## 2.2 Experimental Procedure

Subjects were recruited from the campus of the University of California, Davis. We used ORSEE by Greiner (2004) as recruitment system. None of the subjects participated previously in a similar experiment that we had run earlier in 2007 and that had been analyzed in Pearson and Schipper (2011, 2012). Since our experiment included also auction games, it was advertised as a “market game” mostly via announcements in big classes, in advertisements on Facebook, and through the distribution of leaflets. All sessions were run between February 8 and March 16, 2010, always at 16:00.

Upon arrival at the lab that had nine computer terminals altogether, subjects were seated randomly at a desk with a computer terminal. Computer terminals are separated by dividers and each subject faces the wall of the room. Subjects were given a consent form to read and sign. At every session, the same male native-English speaking experimenter was present to explain the instructions and supervise the experiment.

Every session of the experiment was divided into seven phases:

1. *First Saliva Sample*: Subjects received written instructions for saliva sampling (see Appendix A) and a styrofoam cup that contained a 4.5 ml sterile Nunc Cryo Tube<sup>©</sup> vial. The cup functions simply as a container that prevents the vial from falling over. Each vial had been labeled prior to the experiment with the session and subject number. Subjects also received one piece of chewing gum, Trident<sup>©</sup> Original Flavor to stimulate saliva (see Dabbs, 1991) as well as a sterilized plastic straw through which to drool about 2.5 ml saliva into the vial. After depositing the saliva, each subject closed the vial by screwing the top and placed it back into the cup. The cups with the vials were collected by the experimenter and immediately frozen. Further details of the salivary hormone methodology are discussed in Appendix B.

2. *Holt-Laury Lottery Task*: Subjects received written instructions on the Holt-Laury lottery tasks (see Appendix C). Subject had five minutes to read the instruction. Then the experimenter explained the task to all subjects in public after which questions, if any, were answered in public. The task is conducted on paper-sheets for both gains and losses. All subjects made decisions in private first for the gain domain and only then for the loss domain.<sup>5</sup> In order to eliminate as much as possible any wealth effect on the following tasks, the lotteries were not played out immediately after completing the tasks. After all subjects completed their choices, the paper sheets were collected by the experimenter.

3. *Auction Game*: Each subject received printed instructions for the auction game. The auction game was computerized on z-tree (Fischbacher, 2007) using the same program as Chen, Katuščák, and Ozdenoren (2007, 2009) and Pearson and Schipper (2011, 2012). The correlation between bidding and profits in those auctions and salivary hormones is analyzed in detail in a companion paper, Schipper (2012), where the instructions can be

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<sup>5</sup>Laury and Holt (2008, p. 9) claim that the order of these tasks do not matter. However, we should mention that their experiment differs from ours in that their tasks were separated by the play of a matching pennies game and additional Holt-Laury lottery tasks with varying payoffs were included.

found as well. Since the auction game could not affect behavior in the prior lottery task (except for expectations about future earnings in the auction game), it won't be discussed here any further.

4. *Questionnaire:* After the auction task, subjects completed a computerized questionnaire (see Appendix D). This questionnaire focuses on eliciting demographic information, menstrual cycle information, information relevant for assessing the quality of saliva, information on sexual preferences and sexual behavior, social lifestyle, personality characteristics, emotions during the experiment, dietary preferences, academic grades, etc. The motivation for the large questionnaire is twofold. First, we need to generate a sufficiently long waiting period before collecting the second saliva sample. Second, many factors beyond age, gender, race, such as the use of hormonal contraceptives, pregnancy, menstrual cycle phases etc. may be correlated with salivary hormone levels. See Appendix B for an analysis of some of those factors. Some of the information elicited with the questionnaire are used as controls in our statistical analysis.

4. *Playing out the Holt-Laury Lottery Task:* Once subjects finished the questionnaire, the previously completed paper-sheets on the Holt-Laury lottery tasks were played out in front of the subjects. For each subject, a ten-sided die was rolled four times. The first roll decided which binary choice in the gain domain is selected. The second roll played out this lottery in the gain domain. The third roll decided which binary choice in the loss domain is selected. And the final fourth roll played out this lottery in the loss domain. Payoffs for each subject were noted on the decision sheet of each subject.

5. *Hand Scan:* After playing out the lottery tasks, each subject's right hand (and the right hand only) was scanned with a conventional office image scanner. The purpose of the hand scan is to measure the length of the 2nd and 3rd finger and analyze the digitratio (2D:4D). The second and fourth digits were later measured independently by two separate researchers from the center of the flexion crease proximal to the palm to the top of the digit using the measurement tools in Adobe Photoshop and Gimp. When measuring the fingers, the researchers did not know whether the hand belong to a male or female subject or how this subject behaved in the experiment. The measures used here are based on the averages of both measurements for each finger of each subject respectively. The researchers who measured the digits also recorded when creases were unclear. In the questionnaire we also ask subjects to report on any previous fractures of the relevant digits.

6. *Second Saliva Sample:* About 20 to 30 minutes after the auction task, subjects were asked for a second saliva sample in the same manner as for the first saliva sample. Since it takes about 15 to 30 minutes before effects on hormones become measurable in saliva (see for instance Schultheiss et al., 2005, Kivlighan, Granger, and Booth, 2005, Edwards and O'Neal, 2009, Saad and Vongas, 2009) and only less time had passed between playing out the Holt-Laury lottery tasks and the second saliva sample, this data won't be analyzed here. Schipper (2012) discusses the relationship between salivary hormones in the second saliva sample and bidding and profits in the auction game.

7. *Payment:* At the end of the experiment, subject received in private their total cash

payment from the show up fee, the auction task, and the lottery tasks. The average total earning was US\$19.03 with a maximum of US\$ 48.39 and a minimum of US\$ 5.00. The entire procedure took about 1 hour and 20-30 minutes. The average earning is above what a typical student job would earn in Davis for about the same time. Our lottery task experiment involves losses as well. Losses can typically not be collected from subjects. Yet, subjects knew that they can earn also money in the gain domain of the lottery task as well as from the auctions.

Table 2: Basic Demographics

| Variable              | Number | Mean  | Std. Dev. |
|-----------------------|--------|-------|-----------|
| Subjects              | 208    |       |           |
| Female                | 93     | 0.45  |           |
| Age                   |        | 20.36 | 2.24      |
| White                 | 79     | 0.38  |           |
| Asian                 | 116    | 0.55  |           |
| Hispanic              | 13     | 0.06  |           |
| Black                 | 5      | 0.02  |           |
| Others                | 8      | 0.04  |           |
| GPA                   |        | 3.17  | 0.52      |
| Math                  | 5      | 0.02  |           |
| All Sciences          | 61     | 0.29  |           |
| Economics             | 103    | 0.50  |           |
| Other Social Sciences | 65     | 0.31  |           |
| Humanities            | 20     | 0.10  |           |
| Pregnant              | 1      |       |           |
| Homo- or Bisexual     | 14     | 0.07  |           |

### 3 Results

Table 2 presents the demographics of our data as elicited with the questionnaire (see Appendix D).<sup>6</sup> We had 208 subjects in sessions of 8 subjects each. Out of the 208 subjects, 93 or about 45% are female. Most of our subjects are Asian-americans (55%) followed

<sup>6</sup>Subjects were allowed to select multiple majors and ethnic backgrounds. Thus, the means do not add up to unity.

by Whites (38%).<sup>7</sup> One woman reported that she is pregnant. Since circulating levels of various steroids change during pregnancy, we exclude her from our analysis of salivary hormones and the menstrual cycle information but not in our analysis of gender differences and the digit ratio. Six females and eight males reported to be homo- or bisexual. We do not find robust significant correlations between sexual preferences and salivary hormones.

Figure 1 shows the cumulative frequency of option A for both the gain and the loss domain. Recall that both in the gain and loss domain, a risk neutral individual would choose option A exactly five times. If all subjects were risk neutral, the cumulative frequency would be zero up to five and one thereafter. However, we see that both for gains and losses some subjects choose less than five times option A while others choose more. This suggest that some subjects may be risk seeking while others are risk averse. The cumulative frequency for the gain domain is below the one for the loss domain indicating that subjects' choices may be relatively more risk averse in the gain domain as compared to the loss domain. This finding is consistent with Laury and Holt (2008).

Figure 1: Cumulative Frequency

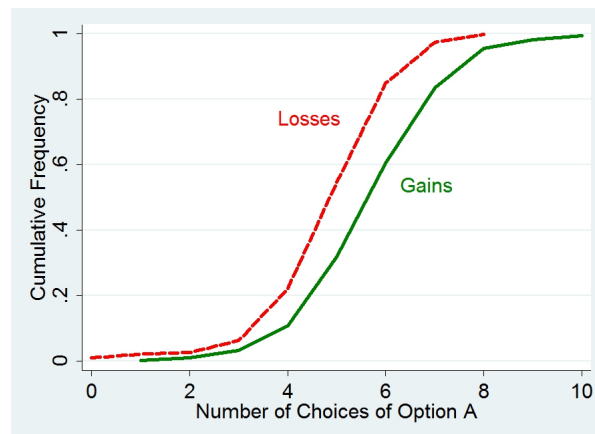


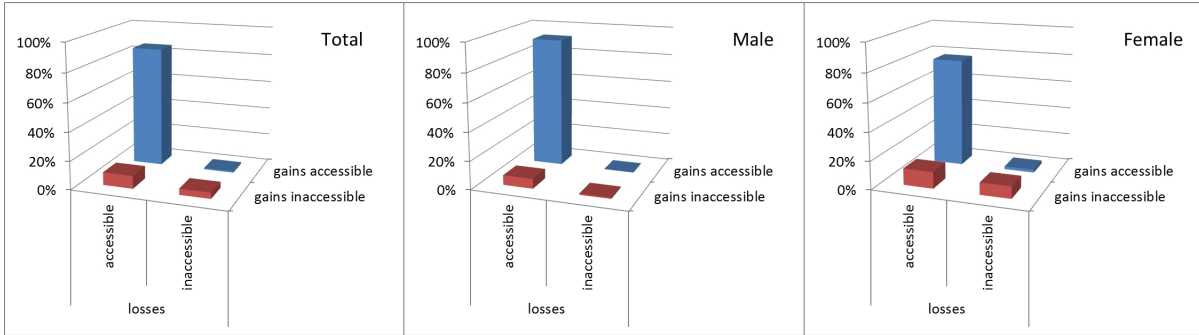
Figure 1 considers choices by all subjects including subjects whose preferences are inaccessible. There are a few inaccessible subjects who do not have an unique cut-off for switching between options A and B or do not respect dominance. The left panel in Figure 2 shows that most of our subjects, 178 out of 208 (86%), are accessible both in the gain and loss domain. However, slightly more subjects are accessible in the loss domain than in the gain domain. We do not know whether this is due to the fact that subjects

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<sup>7</sup>For comparison, the distribution of races among all UC Davis students is 42% white, 38% asian, 3% black, 14% hispanic, and 3% others. See <http://facts.ucdavis.edu/studentheadcountethnicity.lasso>. We don't know why we have a larger fraction of Asians in our sample. It could be that relative more asians are enrolled in majors that we reached with our advertisements. In particular, about 59% of economics students at UC Davis are asian. Another reason could be that Asians were more attracted to our experiments. For instance, Loo et al. (2008) surveying the literature on Chinese gambling find that gambling is widespread preferred form of entertainment among Chinese.

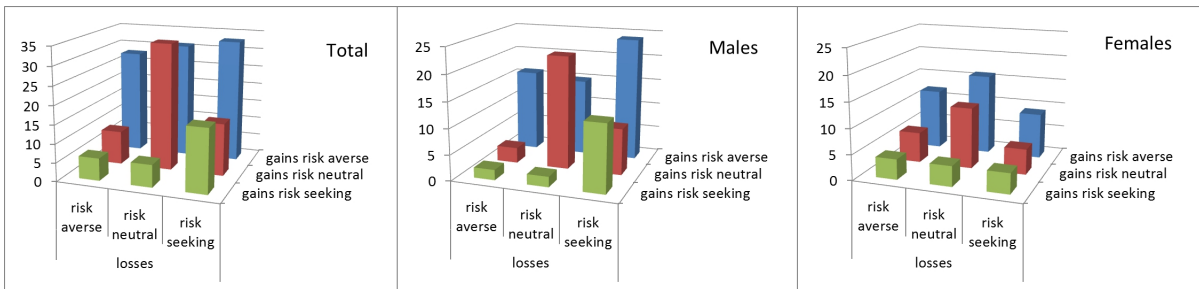
had to choose among the loss lotteries *after* they chose among the gain lotteries and thus had more experience in thinking through the problem or whether subjects are simply more careful in making choices when it comes to losses. Our observations are comparable to Laury and Holt (2008) who observe that 72% of their subjects are accessible.

Figure 2: Fraction of Subjects with (In-)accessible Preferences



We can classify all accessible subjects approximately as choosing risk averse, risk seeking, and risk neutral according to whether they choose option A more, less or exactly five times, respectively (see Section 2.1). The left panel in Figure 3 shows the risk attitudes for both the gain and the loss domain. The modal subjects (34) are risk neutral both in the gain and loss domain followed closely by 33 subjects who are risk averse in the gain domain and risk seeking in the loss domain. Latter subjects display the reflection effect (see Section 2.1). These findings are somewhat different from Laury and Holt (2008). In their treatment that corresponds to ours, they observe that the modal subject exhibits risk aversion both in the gain and loss domains.

Figure 3: Number of Subjects by Risk Attitudes



In the analysis below, we will estimate versions of the following parametric model

$$r_i = \beta_0 + \beta H_i + \gamma C_i + \delta D_i + \zeta M_i + \eta Q_i + \varepsilon_i \quad (1)$$



where  $i$  is the index of the subject,  $r_i$  is the number of choices of option A by subject  $i$  (in either the gain domain or the loss domain),  $\beta_0$  is a constant,  $H_i$  is a vector of salivary hormone variables,  $C_i$  is a dummy indicating the use of hormonal contraceptives by women  $i$ ,  $M_i$  is a vector of dummies indicating the menstrual cycle phase of naturally cycling women,  $D_i$  is the digit ratio of subject  $i$ ,  $Q_i$  is a subset of questionnaire variables including gender, age, race, major of study, and  $\varepsilon_i$  is an unobserved error term of subject  $i$ . The specifications will differ in the subsets of terms considered. Note that whenever we include dummies for all menstrual phases and the use of hormonal contraceptives, we force the coefficient for the gender dummy to zero for all subjects. Moreover, we omit from all regression reports the constant. This model will be estimated with ordinary least squares method (OLS) but we will also consider ordered probit or ordered logit models since the number of choices of option A can be considered as an ordinal variable.

We also estimate specifications analogous to equation (1) where we replace the number of choices of option A by either a binary variable for reflection or a binary variable for accessibility as dependent variable. Because of the binary dependent variable, we will then estimate the model with probit or logit.

To account for heteroscedasticity, we use robust standard errors in all regressions. For robustness checks, we will cluster standard errors on session level in some specifications. Moreover, in order to control for session effects (e.g., sex ratio of the session or possibly degraded quality of saliva samples in earlier sessions as compared to later sessions), we will add in some specifications session dummies or session fixed effects.

Some hormones like salivary testosterone or salivary estradiol are measured in pg/ml while others like salivary progesterone or salivary cortisol are measured in nmol/L. Moreover, we will see in Table 7 and Figure 5 that their absolute levels differ quite a bit. To be better able to interpret the regression results, we standardize hormone levels by dividing them by their standard deviation. For instance, in OLS regressions, the coefficient for any hormone now measures the effect on the number of choices of option A when that hormone level increases by one standard deviation.

For our regression specifications we use the following name conventions: “G” (resp. “L”) signifies that the dependent variable is the number of choices of option A in the *gain* (resp. *loss*) domain. “R” stands for (the binary variable) *reflection*, while “A” stands for (the binary variable) *accessibility*. “F” will denote the *female* subsample and “M” the *male*. Finally, in the last subsection “DR” stands for “digit ratio”.

### 3.1 Gender Effects

The middle and right panels of Figure 3 suggest that relatively fewer women than men are risk seeking in the loss domain while in the gain domain women and men behave quite similar. This observations is confirmed in Table 3. In specification G0A, we regress the number of choices of option A for subjects with accessible preferences in the gain domain on a subset of demographic variables including gender using OLS. We do not find a significant gender effect ( $p = 0.61$ ). This is in contrast to the analogous specification

L0A for the loss domain. Here being female is significantly positively correlated with risk aversion ( $p = 0.019$ ) when controlling for demographics.

Table 3: Gender Effects for Gains & Losses

|                               | (G0A)               | (G0)                | (G1A)               | (L0A)                | (L0)                 | (L1A)               |
|-------------------------------|---------------------|---------------------|---------------------|----------------------|----------------------|---------------------|
| Age                           | -0.0429<br>(0.0419) | -0.0355<br>(0.0429) | -0.0248<br>(0.0439) | -0.0790*<br>(0.0472) | -0.0711<br>(0.0444)  | -0.0490<br>(0.0411) |
| Asian                         | -0.2813<br>(0.2056) | -0.1976<br>(0.1963) | -0.2200<br>(0.2109) | -0.2460<br>(0.1891)  | -0.2936<br>(0.1874)  | -0.2716<br>(0.1897) |
| Other                         | 0.4268<br>(0.2949)  | 0.0956<br>(0.2819)  | 0.3607<br>(0.2823)  | 0.0611<br>(0.2484)   | 0.1643<br>(0.2523)   | 0.0792<br>(0.2457)  |
| GPA                           | -0.0358<br>(0.2332) | 0.0920<br>(0.1833)  | -0.0047<br>(0.2250) | -0.1090<br>(0.1733)  | -0.1769<br>(0.1690)  | -0.1034<br>(0.1703) |
| Mathematics                   | 0.5187<br>(0.7343)  | 0.4717<br>(0.7262)  |                     | 0.0166<br>(0.4863)   | 0.0108<br>(0.4866)   |                     |
| Science & Engineering         | -0.0655<br>(0.2776) | -0.1982<br>(0.2860) |                     | -0.2482<br>(0.2299)  | -0.1917<br>(0.2322)  |                     |
| Economics                     | 0.3960<br>(0.2404)  | 0.2679<br>(0.2646)  |                     | 0.4576**<br>(0.2029) | 0.4140**<br>(0.1967) |                     |
| Social Science                | -0.1246<br>(0.2523) | -0.1363<br>(0.2550) |                     | 0.3091<br>(0.2279)   | 0.2868<br>(0.2258)   |                     |
| Humanities                    | -0.1901<br>(0.3187) | -0.3191<br>(0.3171) |                     | 0.1499<br>(0.2747)   | 0.1614<br>(0.2773)   |                     |
| Female                        | 0.1153<br>(0.2304)  | 0.1988<br>(0.2179)  | -0.0246<br>(0.2138) | 0.4290**<br>(0.1812) | 0.4058**<br>(0.1804) | 0.3139*<br>(0.1850) |
| <i>Number of Observations</i> | 174                 | 202                 | 174                 | 191                  | 202                  | 191                 |
| $R^2$                         | 0.0550              | 0.0357              | 0.0208              | 0.1059               | 0.0995               | 0.0434              |

Robust standard errors in parentheses; Significance levels: \*10%; \*\* 5%; \*\*\* 1%.

Specifications G0A and L0A just consider choices of accessible subjects in the gain and loss domain, respectively. The middle and right panels of Figure 2 reveal that preferences of men are slightly more accessible than references of women. 77% of females while 92% of males are accessible. Specification A0 in Table 4 confirms that on average preferences of women are significantly less accessible ( $p = 0.012$ ) when controlling for demographics. We regress the binary variable accessible/inconsistent on a subset of demographic variables including gender using logit. As we explained in Section 2.1, we do not know why subjects' preferences are inaccessible. It could be that the subject is not maximizing expected payoffs. But it could also well be that a subject is indifferent or just making a mistake in filling out the decision sheet. In the last two cases, we would "misclassify" subjects if we consider them as inconsistent although they actually have consistent risk attitudes. Moreover, it could be that such misclassification is correlated with a particular risk attitude and that this misclassification is especially prevalent in females.

Thus, when we dropped inaccessible subjects in specifications G0A and L0A, we may have introduced a selection bias. To check for such a bias, we estimate analogous specifications G0 and L0 in which we consider as dependent variable the number of choices of option A of all subjects no matter whether they are accessible or inaccessible. This

increases the number of observations but presumably also adds some noise. Our results remain qualitatively unchanged.

Table 4: Gender Effects for Reflection & Accessibility

|                               | (R0)                 | (R1)                 | (A0)                   |
|-------------------------------|----------------------|----------------------|------------------------|
| Age                           | -0.0095<br>(0.1073)  | -0.0181<br>(0.0945)  | 0.0673<br>(0.1026)     |
| Asian                         | 0.1327<br>(0.4640)   | 0.2569<br>(0.4492)   | -0.4637<br>(0.4822)    |
| Other                         | 1.3296**<br>(0.5889) | 1.1899**<br>(0.5622) | -0.2523<br>(0.6925)    |
| GPA                           | -0.0434<br>(0.4789)  | 0.0817<br>(0.4416)   | 0.4919<br>(0.3685)     |
| Mathematics                   | 1.5493<br>(0.9439)   |                      |                        |
| Science & Engineering         | 0.5136<br>(0.6816)   |                      | 0.4357<br>(0.6034)     |
| Economics                     | 0.0070<br>(0.6182)   |                      | -0.1213<br>(0.5698)    |
| Social Science                | -0.7085<br>(0.5843)  |                      | 0.0115<br>(0.5356)     |
| Humanities                    | -0.6779<br>(0.9319)  |                      | 0.4568<br>(0.8255)     |
| Female                        | -0.7108<br>(0.5119)  | -0.8193*<br>(0.4560) | -1.2331***<br>(0.4681) |
| <i>Number of Observations</i> | 172                  | 172                  | 202                    |

Robust standard errors in parentheses; Significance levels: \*10%; \*\* 5%; \*\*\* 1%.

Another reason for why we may not find a gender effect in specifications G0A and G0 is that regressors are correlated. In particular, females may select on average into different majors than males. For instance, all of our five math majors are male and 68% of our econ majors are male. Therefore in specifications G1A and L1A we drop major of study. There is still no significant gender effect for gains ( $p = 0.909$ ) and the gender effect for losses is now just marginally significant ( $p = 0.091$ ).

Figure 4 shows that females' risk preferences in both the gain and loss domains are slightly more similar to each other than males' risk preferences. The middle and right panels of Figure 3 seem to suggest that relatively fewer women display the reflection effect. Yet, when we regress for accessible subjects the binary variable for the reflection effect on a subset of demographic variables including gender using logit in specification R0 (Table 4), we do not find a significant gender effect ( $p = 0.165$ ). Again, it could be that variables for major of study absorb some of the gender effect since some majors are more popular for men than for women and vice versa. When we drop the the dummy variables for major of study in specification R1 in Table 4, the coefficient for female becomes marginally significant ( $p = 0.072$ ). It appears that females are less likely to display the reflection effect as compared to white males.

Figure 4: Cumulative Frequency by Gender



Our conclusions remain qualitatively unchanged if instead of OLS in Table 3 we use ordered logit or probit and instead of logit in Table 4 we use probit or if we add further controls like body mass index (BMI), number of siblings or if we drop all remaining demographic controls in G1A and L1A etc. When we control for session fixed effects, the coefficient for the gender dummy slightly increases (e.g.  $\beta = 0.56$ ,  $p = 0.007$  in a specification analogous to L1A). If we control for session fixed effects in the analysis of the reflection effect in a specification analogous to R0, the coefficient for the reflection effect slightly increases and becomes marginally significant ( $\beta = -0.88$ ,  $p = 0.076$ ). We summarize our findings as follows:

**Observation 1 (Gender effects)** *We do not find significant gender effects for risk aversion in the gain domain. In the loss domain, females are significantly more risk averse than males. Preferences of females are significantly less accessible than males. Females are less likely to exhibit reflection but this observation is just marginally significant when controlling for demographics.*

### 3.2 Hormonal Contraceptives

Roughly 25.6% of women in our sample administer hormonal contraceptives. This number is reasonable given the age of women and their ethnic background.<sup>8</sup> Hormonal contraceptives manipulate hormone levels and may thus influence behavior. Some women in our sample using hormonal contraceptives provided us with the exact name of the

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<sup>8</sup>The United States Department of Health and Human Services (2010) estimates that in the US roughly over 11% of asian, hispanic, and black women between 15 to 44 years of age use the pill compared to over 21% of white women. The use of the pill varies also with age. In the age group 15 to 19, it is slightly over 15%, while it increases to 26% in the age group 20 to 24. Note that the mean age of women in our sample is 20.1 years.

contraceptive and we were able to evaluate their prescribed administration schedules and active ingredients. The contraceptives reported can be classified into three categories: First, there are injections like Depo Provera. This is a long-acting reversible contraceptive acting over 12 weeks containing as the active ingredient only a progestin, a synthetic version of progesterone. Second, some women use the NuvaRing, a flexible vaginal ring that when placed in the vagina releases both a progestin as well as estradiol over a period of three weeks, after which it is removed for a one-week break during which a withdrawal bleeding occurs. Finally, there are oral birth control pills. While some of the pills available may contain as the active ingredient a progestin only, all the pills reported in our experiments contained both a progestin as well as estradiol. There are oral contraceptives that contain the active ingredient (sometimes with changing concentration) for three weeks and an inert ingredient for one week during which a withdrawal bleeding usually occurs (e.g. Avian, Desogen, Junel, Microgestin, Ortho-Tri-Cyclen, Sprintec, and Yasmin). Then there are oral contraceptives that contain the active ingredient for 24 days after which an inert ingredient is taken for 4 days during which withdrawal bleeding usually occurs (e.g. Yaz). Finally, there are extended cycle oral contraceptives that contain an active ingredient for 84 days after which an inert ingredient is used for 7 days during which withdrawal bleeding usually occurs (e.g. Seasonale). Except for Depo Provera, all hormonal contraceptives reported involve a regular break during which circulating levels of progesterone are expected to be lower than when active ingredients are taken. This break may affect behavior. Yet, given the information in our sample we were able to classify only one woman as likely being in the break. Therefore we did not separate the sample into women in the “pill break” and women not being in the “pill break” but just use one dummy variable to indicate the use of hormonal contraceptives.

All hormonal contraceptives contain some form of progestin, a synthetic version of progesterone. Progesterone may have a sedating effect by acting as allosteric modulator of neurotransmitter receptors such as GABA-A (see Pluchino et al., 2006, van Broeckhoven et al., 2006).<sup>9</sup> Hence, one may reasonably expect that the use of hormonal contraceptives would reduce risk-taking. On the other hand, different hormonal contraceptives contain different progestins, and different progestins have different effects on the brain. Not all progestins can be converted into the GABA-A receptor-active metabolites (Pluchino et al., 2009).

In Table 5 we present results from regressions of the number of choices of option A by accessible subjects on hormonal contraceptives and a subset of demographic variables using OLS. Specification G2 applies to the gain domain and the full sample, while specification L2 is on the loss domain. The use of hormonal contraceptives is not significant ( $p = 0.268$  and  $p = 0.910$  for G2 and L2, respectively). We also obtain a null result when we analyze the female subsample separately in specifications G2F and L2F.

The logit specifications R2 and R2F in Table 6 reveal that the use of contraceptives is not significantly correlated with reflection both for the full sample ( $p = 0.939$  in R2) and

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<sup>9</sup>We thank Coren Apicella (private communication) for drawing our attention to the connection between progesterone and GABA-A.

Table 5: Contraceptives and Gains &amp; Losses

|                               | (G2)                | (L2)                 | (G2F)                 | (L2F)                |
|-------------------------------|---------------------|----------------------|-----------------------|----------------------|
| Age                           | -0.0477<br>(0.0428) | -0.0794*<br>(0.0478) | -0.0820<br>(0.0587)   | -0.0174<br>(0.0467)  |
| Asian                         | -0.3102<br>(0.2038) | -0.2490<br>(0.1957)  | -0.5471**<br>(0.2697) | -0.0508<br>(0.3623)  |
| Other                         | 0.3687<br>(0.3036)  | 0.0560<br>(0.2613)   | 0.7168**<br>(0.3172)  | 0.8331**<br>(0.3980) |
| GPA                           | -0.0497<br>(0.2363) | -0.1096<br>(0.1733)  | -0.3803<br>(0.4544)   | -0.3528*<br>(0.1985) |
| Mathematics                   | 0.5489<br>(0.7352)  | 0.0192<br>(0.4900)   |                       |                      |
| Science & Engineering         | -0.0383<br>(0.2778) | -0.2461<br>(0.2332)  | -0.1893<br>(0.3672)   | -0.2722<br>(0.3778)  |
| Economics                     | 0.4072*<br>(0.2406) | 0.4587**<br>(0.2030) | 0.3969<br>(0.3425)    | 0.6420**<br>(0.3153) |
| Social Science                | -0.0852<br>(0.2516) | 0.3129<br>(0.2337)   | -0.4698<br>(0.3372)   | 0.1768<br>(0.3676)   |
| Humanities                    | -0.1759<br>(0.3149) | 0.1504<br>(0.2759)   | -0.6634**<br>(0.3255) | 0.4515<br>(0.5420)   |
| Female                        | 0.1985<br>(0.2703)  | 0.4364**<br>(0.2151) |                       |                      |
| Contraceptives                | -0.3145<br>(0.2830) | -0.0316<br>(0.2796)  | -0.2984<br>(0.2738)   | 0.2129<br>(0.3235)   |
| <i>Number of Observations</i> | 174                 | 191                  | 71                    | 80                   |
| R <sup>2</sup>                | 0.0588              | 0.1060               | 0.1407                | 0.1609               |

Robust standard errors in parentheses; Significance levels: \*10%; \*\* 5%; \*\*\* 1%.

within the female subsample ( $p = 0.404$  in R2F).

With respect to the accessibility of risk preferences, the logit specifications A2 and A2F in Table 6 show that women on hormonal contraceptives are significantly more accessible than white males ( $p = 0.035$  in A2) and women who do not take hormonal contraceptives ( $p = 0.024$  in A2F). We can think of two explanations for this finding. First, as mentioned above, all hormonal contraceptives contain progestins, a synthetic version of progesterone. Natural progesterone typically raises after ovulation (see Figure 8) and prepares the women for pregnancy. In principle, a women could be be with child after ovulation. There may be an evolutionary advantage to make more consistent decisions when potentially being with child.<sup>10</sup> Second, the finding may be due to a selection effect rather than a causal effect. In particular, women who decide to take hormonal contraceptives may differ from other women in there consistency of choices to begin with. It may be because they are more consistent in their choices that they decide to use hormonal contraceptives. More

<sup>10</sup>This begs an explanations for why it would be advantageous from an evolutionary point of view to be relatively less consistent with lower progesterone. A potential explanation could be that inconsistent behavior may simply raise the attention of potential mates in the follicular phase or that indifference between options avoids conflicts about resources.

Table 6: Contraceptives and Reflection &amp; Accessibility

|                               | (R2)                 | (R2F)               | (A2)                   | (A2F)                |
|-------------------------------|----------------------|---------------------|------------------------|----------------------|
| Age                           | -0.0102<br>(0.1081)  | -0.6296<br>(0.4360) | 0.0917<br>(0.1044)     | 0.1364<br>(0.1343)   |
| Asian                         | 0.1284<br>(0.4560)   | -0.8698<br>(0.9387) | -0.3548<br>(0.4968)    | -0.4935<br>(0.6661)  |
| Other                         | 1.3209**<br>(0.5984) | -0.3332<br>(1.3825) | 0.0308<br>(0.7262)     | 0.5855<br>(1.1222)   |
| GPA                           | -0.0458<br>(0.4814)  | 0.8380<br>(1.2056)  | 0.5828<br>(0.3699)     | 0.9525*<br>(0.4976)  |
| Mathematics                   | 1.5524<br>(0.9463)   |                     |                        |                      |
| Science & Engineering         | 0.5170<br>(0.6865)   | 0.5937<br>(1.0876)  | 0.3980<br>(0.6218)     | 0.1436<br>(0.8293)   |
| Economics                     | 0.0075<br>(0.6188)   | 1.4013<br>(1.0121)  | -0.1497<br>(0.5686)    | -0.4985<br>(0.7580)  |
| Social Science                | -0.7041<br>(0.5996)  | -0.4179<br>(1.1325) | -0.2455<br>(0.5606)    | -0.4583<br>(0.8469)  |
| Humanities                    | -0.6773<br>(0.9320)  |                     | 0.4854<br>(0.7965)     | -0.2186<br>(0.8966)  |
| Female                        | -0.6949<br>(0.5469)  |                     | -1.4711***<br>(0.4842) |                      |
| Contraceptives                | -0.0700<br>(0.9111)  | -0.9156<br>(1.0577) | 1.5098**<br>(0.7072)   | 1.7236**<br>(0.7626) |
| <i>Number of Observations</i> | 172                  | 69                  | 202                    | 90                   |

Robust standard errors in parentheses; Significance levels: \*10%; \*\* 5%; \*\*\* 1%.

conclusive evidence could be obtained in an experiment in which oral contraceptives and a placebo are blindly and randomly assigned to women. Obviously, such an experiment would be rather difficult to conduct. Moreover, women who would agree to participate in such a “risky” experiment may systematically differ in their risk preferences and choice consistency from the rest of the population.

Our observations are robust to replacing OLS with ordered logit or ordered probit in Table 5, logit with probit in Table 6, adding further demographic controls, dropping controls for major of study, controlling for session fixed effects, or clustering standard errors on the session level.

**Observation 2 (Hormonal Contraceptives)** *Females who use hormonal contraceptives do not show risk attitudes differently from white males or females who do not use hormonal contraceptives. However, females on hormonal contraceptives are significantly more likely to make “consistent” choices than white males or females who do not use hormonal contraceptives.*

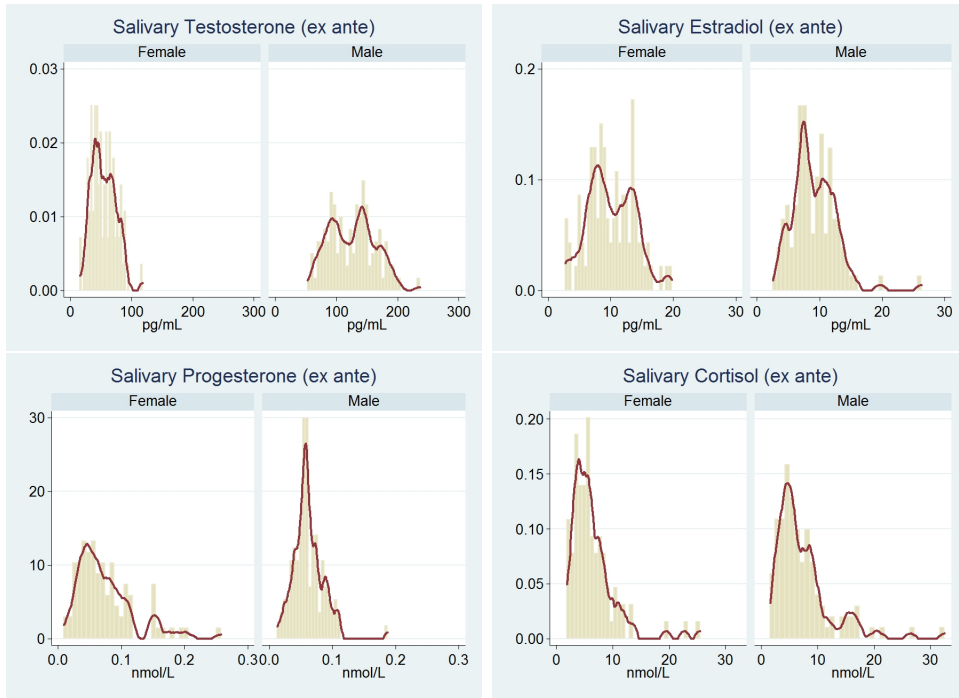
Table 7: Ex Ante Salivary Hormones by Gender

| Salivary Hormone      | Female  |           |        |         | Male     |           |        |         |
|-----------------------|---------|-----------|--------|---------|----------|-----------|--------|---------|
|                       | Mean    | Std. Dev. | Min    | Max     | Mean     | Std. Dev. | Min    | Max     |
| Testosterone (pg/mL)  | 54.3643 | 19.7774   | 15.586 | 117.945 | 125.7049 | 37.9870   | 52.645 | 236.950 |
| Estradiol (pg/mL)     | 10.0680 | 3.7869    | 2.784  | 19.819  | 9.1036   | 3.4890    | 2.550  | 26.305  |
| Progesterone (nmol/L) | 0.0749  | 0.0461    | 0.009  | 0.258   | 0.0623   | 0.0242    | 0.013  | 0.188   |
| Cortisol (nmol/L)     | 6.4394  | 4.0129    | 1.851  | 25.462  | 7.4268   | 5.0665    | 1.549  | 32.553  |

### 3.3 Salivary Hormones

From each subject we collected saliva after they arrived for the experiment about 5 to 8 minutes *before* they made decisions in the Holt-Laury lottery tasks. We call these the *ex ante* measures in order to distinguish them from the saliva samples collected at the end of the entire experiment. The amount of saliva we collected from one subjects was not sufficient to assay progesterone and cortisol. This subject is excluded in the analysis of those salivary hormones. Table 7 provides the summary statistics for salivary hormones by gender. Figure 5 displays histograms and kernel distributions by gender.

Figure 5: Densities of Salivary Hormones by Gender

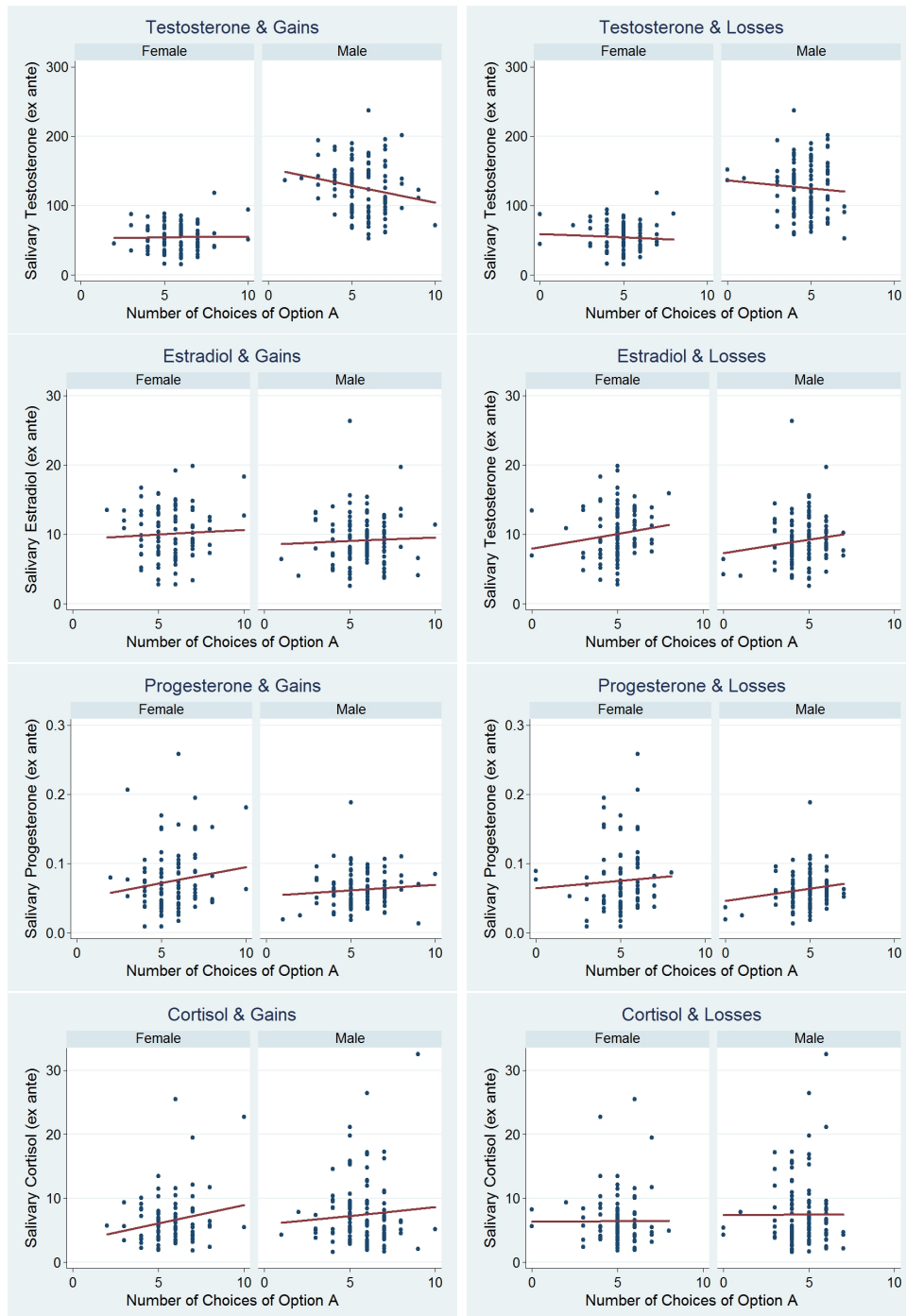


The relationships between ex ante salivary hormones and risk aversion in both the



gain and loss domains are preliminarily explored in Figure 6 in which we print for each hormone a scatter plot and fit a linear regression between the hormone level and the number of choices of option A.

Figure 6: Salivary Hormones and Risk Taking by Gender



In the upper two panels of Figure 6 we observe that higher testosterone is negatively correlated with risk aversion in males but not in females. This is more pronounced in the gain (upper left panel) than in the loss (upper right panel) domain. That is, testosterone is negatively correlated with risk aversion in males. A positive correlation is observed between estradiol and risk aversion for both males and females in the loss domain (second upper right panel) but not in the gain domain (second upper left panel). Similarly, a positive correlation is observed between progesterone and risk aversion for both males and females in both the gain and loss domains but the correlation is more pronounced for females and in the gain domain. Finally, a positive correlation is observed between cortisol and risk aversion for both males and females in the gain domain but not in the loss domain.

Table 8: Salivary Hormones: Full Sample

|                               | (G3)                   | (G4)                   | (L3)                | (L4)                 |
|-------------------------------|------------------------|------------------------|---------------------|----------------------|
| Age                           |                        | -0.0379<br>(0.0411)    |                     | -0.0826*<br>(0.0488) |
| Asian                         |                        | -0.2848<br>(0.1952)    |                     | -0.2242<br>(0.1994)  |
| Other                         |                        | 0.2838<br>(0.3136)     |                     | 0.0595<br>(0.2637)   |
| GPA                           |                        | -0.0699<br>(0.2380)    |                     | -0.0742<br>(0.1806)  |
| Mathematics                   |                        | 0.5604<br>(0.8799)     |                     | 0.0951<br>(0.4526)   |
| Science & Engineering         |                        | 0.0117<br>(0.2753)     |                     | -0.2726<br>(0.2506)  |
| Economics                     |                        | 0.4113*<br>(0.2320)    |                     | 0.4415**<br>(0.2127) |
| Social Science                |                        | -0.0831<br>(0.2667)    |                     | 0.2600<br>(0.2476)   |
| Humanities                    |                        | -0.2872<br>(0.2982)    |                     | 0.1305<br>(0.2772)   |
| Female                        | -0.8178***<br>(0.3103) | -0.6184*<br>(0.3231)   | -0.1068<br>(0.3017) | 0.1306<br>(0.3200)   |
| Testosterone                  | -0.5128***<br>(0.1588) | -0.4919***<br>(0.1773) | -0.2232<br>(0.1429) | -0.1714<br>(0.1449)  |
| Estradiol                     | 0.0366<br>(0.1093)     | 0.0428<br>(0.1259)     | 0.1542<br>(0.0936)  | 0.1066<br>(0.0978)   |
| Progesterone                  | 0.1245<br>(0.1233)     | 0.1299<br>(0.1353)     | 0.0543<br>(0.0797)  | 0.0524<br>(0.0857)   |
| Cortisol                      | 0.3116***<br>(0.1091)  | 0.3065***<br>(0.1110)  | 0.0629<br>(0.0829)  | 0.0513<br>(0.0877)   |
| Contraceptives                | -0.1969<br>(0.2817)    | -0.2574<br>(0.2756)    | 0.0851<br>(0.2356)  | -0.0364<br>(0.2827)  |
| <i>Number of Observations</i> | 178                    | 172                    | 195                 | 189                  |
| <i>R<sup>2</sup></i>          | 0.0963                 | 0.1430                 | 0.0448              | 0.1235               |

Robust standard errors in parentheses; Significance levels: \*10%; \*\* 5%; \*\*\* 1%.

We seek to corroborate these preliminary observations with multivariate regressions that control also for the use of hormonal contraceptives, gender, and further demographics in Table 8. In specification G3 we regress the number of choices of option A by accessible subjects on the use of hormonal contraceptives, gender, and salivary hormone levels using OLS. We find that testosterone is significantly negatively correlated with the number of choices of option A for gains ( $p = 0.006$ ). We also find that cortisol is significantly positively correlated with the number of choices of option A for gains ( $p = 0.006$ ). In accordance with Figure 6 we find no significant correlation between estradiol and choice under risk ( $p = 0.738$ ). But we also do not find any significant effect of progesterone for gains ( $p = 0.314$ ) which is in contrast to what is suggested in Figure 6.

Analogously, specifications L3 and L4 use the number of choices of option A in the loss domain by accessible subjects as dependent variable. We do not find any significant correlations between any salivary hormone and choice behavior. In case of estradiol, this is somewhat contrary to what Figure 6 seem to suggest.

We subjected our findings to various robustness checks. Our conclusions remain unchanged if we control for further demographics, addition of further controls for the quality of saliva, cluster standard errors on sessions, employ order probit or ordered logit instead of OLS, or add session dummies or session fixed effects. With session fixed effects, testosterone becomes significant for losses in a specification analogous to L3 ( $\beta = -0.31$ ,  $p = 0.043$ ) but this is not robust to adding demographic controls analogous to L4.

We should note that testing for the hypothesis that any of our four salivary hormones are significantly correlated with risk aversion involves *multiple testing* of four hormones. This may lead to errors of inference, in particular in the underestimation of false positives. We correct for multiple testing using the conservative Bonferroni correction. If the desired significance level is 5%, then the Bonferroni corrected significance level for each hormone should be 1.25% (since there are four hormones). Thus, any hormone that is significant at the 1.25% level is also Bonferroni corrected significant at the 5% level. Using this conservative method of statistical inference does not change our qualitative conclusions drawn from Table 8.

With regard to the reflection effect, the logit specification R3 in Table 9 shows that there is no significant correlation between any hormone and reflection in the full sample except for a marginally significant positive correlation with progesterone ( $p = 0.091$ ). This finding is not robust to controlling for session fixed effects.

Finally, with regard to the accessibility of preferences and salivary hormones, the logit specification A3 in Table 10 shows no significant correlation in the full sample between any hormone and accessibility. This holds when controlling for gender and further demographic variables. When controlling for session fixed effects, we observe marginal significant effects for testosterone and cortisol. Testosterone is negatively correlated with accessibility ( $\beta = -1.09$ ,  $p = 0.082$  in a specification analogous to A3 but with session dummies) and cortisol is positively correlated with accessibility ( $\beta = 0.77$ ,  $p = 0.063$  in a specification analogous to A3 but with session dummies). With Bonferroni correction, these observations are insignificant.

Table 9: Reflection

|                               | (R3)                 | (R3F)                 | (R4F)                  | (R3M)                |
|-------------------------------|----------------------|-----------------------|------------------------|----------------------|
| Age                           | -0.0124<br>(0.1121)  | -0.8441**<br>(0.3847) | -0.6810*<br>(0.3683)   | 0.2010<br>(0.1670)   |
| Asian                         | 0.1507<br>(0.4745)   | -2.1581<br>(1.3999)   | -1.4608<br>(1.4225)    | 0.3690<br>(0.6433)   |
| Other                         | 1.4487**<br>(0.6112) | 0.3249<br>(1.4861)    | -0.6299<br>(1.4169)    | 1.9037**<br>(0.8426) |
| GPA                           | -0.0970<br>(0.5089)  | 2.8472<br>(1.8744)    | 2.2238<br>(1.6525)     | -1.0325<br>(0.8049)  |
| Mathematics                   | 1.5722<br>(1.0230)   | (empty)               | (empty)                | 1.4209<br>(1.0196)   |
| Science & Engineering         | 0.5980<br>(0.7275)   | 0.7376<br>(1.1520)    | 1.8067<br>(1.5583)     | 1.0197<br>(0.9278)   |
| Economics                     | -0.0595<br>(0.6187)  | 0.3713<br>(1.0334)    | 1.7529<br>(1.6652)     | -0.4178<br>(0.7008)  |
| Social Science                | -0.6168<br>(0.6220)  | 0.7932<br>(1.2568)    | 2.0822<br>(1.6310)     | -0.4745<br>(0.8128)  |
| Humanities                    | -0.8806<br>(0.9962)  | (empty)               | (empty)                | -0.4285<br>(1.0780)  |
| Female                        | -1.3233<br>(0.8998)  |                       |                        |                      |
| Testosterone                  | -0.2581<br>(0.3651)  | 4.5232***<br>(1.5492) | 3.3205**<br>(1.4131)   | -0.5674<br>(0.4520)  |
| Estradiol                     | -0.1924<br>(0.2355)  | -0.9985*<br>(0.5920)  | -0.6407<br>(0.5705)    | -0.4309<br>(0.3588)  |
| Progesterone                  | 0.4003*<br>(0.2372)  | 1.3672***<br>(0.4466) | 0.9506**<br>(0.4044)   | 0.1619<br>(0.3877)   |
| Cortisol                      | 0.0720<br>(0.1915)   | 0.2482<br>(0.5437)    | 0.2764<br>(0.4050)     | 0.0480<br>(0.2551)   |
| Contraceptives                | -0.0200<br>(0.9124)  | -0.3824<br>(0.9818)   | -18.5525**<br>(7.3330) |                      |
| Contracept. x Testost.        |                      |                       | 7.0714<br>(6.7830)     |                      |
| Contracept. x Estradiol       |                      |                       | -9.2044***<br>(1.4373) |                      |
| Contracept. x Progest.        |                      |                       | 12.6616***<br>(1.6183) |                      |
| <i>Number of Observations</i> | 170                  | 62                    | 62                     | 102                  |

Robust standard errors in parentheses; Significance levels: \*10%; \*\* 5%; \*\*\* 1%.

**Observation 3 (Steroids effects in the full sample)** *Controlling for gender, testosterone is significantly negatively correlated with risk aversion and cortisol is significantly positively correlated with risk aversion. This holds also if we use Bonferroni correction to account for multiple testing. For reflection and accessibility, we do not find any robust significant correlation between salivary hormones when controlling for gender.*

At this point, it may be worthwhile to revisit gender effects. Note that in specification G3 of Table 8 gender becomes now significant ( $p = 0.009$ ) but its sign is in the unexpected

Table 10: Accessibility

|                               | (A3)                  | (A3F)                 | (A4F)                 | (A3M)                 |
|-------------------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Age                           | 0.1257<br>(0.1213)    | 0.1063<br>(0.1132)    | 0.1024<br>(0.1185)    | 0.0714<br>(0.2494)    |
| Asian                         | -0.3976<br>(0.4929)   | -0.5237<br>(0.6382)   | -0.6740<br>(0.6986)   | 0.1342<br>(0.8690)    |
| Other                         | -0.0200<br>(0.7554)   | 0.2817<br>(1.1004)    | 0.1910<br>(1.1580)    | -1.6858<br>(1.2903)   |
| GPA                           | 0.5535<br>(0.3944)    | 1.2870**<br>(0.5471)  | 1.2684**<br>(0.5492)  | -1.0126<br>(0.6673)   |
| Science & Engineering         | 0.6423<br>(0.6740)    | 0.8072<br>(1.2329)    | 0.9263<br>(1.4484)    | 2.3507<br>(1.5396)    |
| Economics                     | -0.0174<br>(0.6018)   | -0.0601<br>(1.0306)   | 0.0779<br>(1.2250)    | 0.3602<br>(0.7815)    |
| Social Science                | 0.0252<br>(0.6061)    | 0.2442<br>(1.1451)    | 0.3152<br>(1.2853)    | 1.3926<br>(0.8642)    |
| Humanities                    | 0.4996<br>(0.8005)    | 0.4538<br>(1.1215)    | 0.3585<br>(1.2680)    |                       |
| Female                        | -1.8793**<br>(0.8633) |                       |                       |                       |
| Testosterone                  | -0.2494<br>(0.3946)   | -1.9310**<br>(0.9571) | -2.2117**<br>(1.1220) | 0.1189<br>(0.4149)    |
| Estradiol                     | -0.2691<br>(0.2330)   | 0.4415<br>(0.3880)    | 0.3430<br>(0.4167)    | -1.2662**<br>(0.6348) |
| Progesterone                  | 0.1988<br>(0.2020)    | 0.2086<br>(0.2291)    | 0.2415<br>(0.2566)    | -0.1090<br>(0.6507)   |
| Cortisol                      | 0.3870<br>(0.2576)    | 0.7292*<br>(0.4071)   | 0.8029*<br>(0.4341)   | 0.1050<br>(0.3401)    |
| Contraceptives                | 1.6088**<br>(0.7262)  | 1.5569*<br>(0.8163)   | -2.1255<br>(1.9097)   |                       |
| Contracept. x Testost.        |                       |                       | 2.5422<br>(2.7744)    |                       |
| Contracept. x Estradiol       |                       |                       | 1.4587<br>(1.1651)    |                       |
| Contracept. x Progest.        |                       |                       | -1.0694*<br>(0.6031)  |                       |
| <i>Number of Observations</i> | 200                   | 89                    | 89                    | 111                   |
| R <sup>2</sup>                |                       |                       |                       |                       |

Robust standard errors in parentheses; Significance levels: \*10%; \*\* 5%; \*\*\* 1%.

direction. That is, controlling for salivary testosterone, estradiol, progesterone, and cortisol, females are significantly *more risk seeking* than white males! This suggests that there is a gender effect beyond sex steroids and that the sign of this gender effect is opposite to the “uncontrolled” gender effect suggested in the literature. It appears as if sex hormones jointly “counter” a negative gender effect. If the “uncontrolled” gender effect is interpreted as decomposed into the “controlled gender effect” and the “effect of sex steroids”, then “sex steroids” seem to “overcompensate” the “controlled” gender effect that it is typically observed in choice under risk. The question is to what extent

this holds up to the addition of further controls. Specification G4 shows that while our findings for hormones in the previous regression are robust to the inclusion of further demographic variables such as age, race, GPA, and major of study, the finding on gender is not. The effect of gender declines slightly (in absolute terms) and is now just marginally significant ( $p = 0.057$ ). This of course is not too surprising since the choice of major is itself correlated with gender. Indeed, the dummy for being female becomes significant if dummies for majors of study are dropped ( $\beta = -0.68$ ,  $p = 0.034$ ).

Previous observations taken together suggest that females should be less prone to the reflection effect. Indeed, this was already suggested by Figure 4 but we couldn't find any robust significant effect in previous subsection. Specification R3 in Table 9 shows that when controlling for sex steroids females are just insignificantly less prone to the reflection effect ( $p = 0.141$ ) than males.

In all specifications analyzing the correlation between salivary hormones and risk taking, we consider just choices by accessible subjects in the gain and loss domain respectively. But we know from specification A0 in Table 4 that on average women's preferences are significantly less accessible. Could this be effected through sex hormones? In Table 10 we present logit regression A3 in which we regress the binary variable accessible/inaccessible on salivary hormones, the use of hormonal contraceptives as well as a subset of demographic variables. First, we observe in specification A3 that our previous finding that women are significantly less accessible survives when we control for salivary hormones and the use of hormonal contraceptives. We interpret this as suggesting that there is something beyond differences in sex hormones that explains why women may show less accessible preferences in our tasks.

**Observation 4 (Gender effects revisited - Controlling for sex steroids)** *For gains, females are significantly more risk seeking than white males when controlling for salivary sex steroids. No such finding appears for losses. Females are insignificantly less prone to reflection than white males. Preferences of females are significantly less accessible than preferences of white males even when we control for sex hormones and the use of hormonal contraceptives.*

Figure 6 suggests gender differences in the effect of hormones on choice behavior. For instance, we should observe the effect of testosterone for males only but not for females. To investigate such sexual dimorphisms, we split the sample into subsamples of males and females. Specifications G3F and G3M in Table 11 are specifications analogous to G3 in Table 8 but for the female and male subsamples, respectively. We observe that testosterone continues to be significantly negatively correlated with the number of consistent choices of option A in the gain domain for males ( $p = 0.008$ ) but not females ( $p = 0.940$ ). This positive finding for males is also significant when accounting for multiple testing using Bonferroni correction. Our positive finding for cortisol reappears for females but there it is just marginally significant ( $p = 0.055$ ) but not in males ( $p = 0.110$ ). This is considered to be insignificant if we account for multiple testing of four hormones using Bonferroni

Table 11: Salivary Hormones by Gender

|                               | (G3F)                | (G4F)                | (L3F)               | (G3M)                  | (G4M)                 | (L3M)                 |
|-------------------------------|----------------------|----------------------|---------------------|------------------------|-----------------------|-----------------------|
| Age                           | -0.0499<br>(0.0553)  | -0.0452<br>(0.0542)  | -0.0300<br>(0.0463) | -0.0079<br>(0.0682)    | -0.0047<br>(0.0714)   | -0.1871**<br>(0.0743) |
| Asian                         | -0.5814*<br>(0.3077) | -0.5194<br>(0.3258)  | -0.0112<br>(0.4066) | -0.1120<br>(0.2719)    | -0.1241<br>(0.2698)   | -0.3243<br>(0.2231)   |
| Other                         | 0.8202**<br>(0.3937) | 0.8560**<br>(0.4234) | 0.8164*<br>(0.4229) | 0.0183<br>(0.4821)     | -0.0567<br>(0.4991)   | -0.4993<br>(0.3261)   |
| GPA                           | -0.2306<br>(0.3650)  | -0.2169<br>(0.3533)  | -0.2445<br>(0.2082) | 0.0023<br>(0.3235)     | 0.0087<br>(0.3268)    | 0.1548<br>(0.3100)    |
| Mathematics                   |                      |                      |                     | 0.5954<br>(0.9151)     | 0.6340<br>(0.9578)    | 0.2663<br>(0.4496)    |
| Science & Engineering         | -0.0197<br>(0.3521)  | -0.0767<br>(0.3587)  | -0.2305<br>(0.3999) | -0.0130<br>(0.3800)    | 0.0222<br>(0.3772)    | -0.2924<br>(0.3210)   |
| Economics                     | 0.3512<br>(0.3588)   | 0.2931<br>(0.3711)   | 0.6484*<br>(0.3249) | 0.4352<br>(0.3144)     | 0.5315<br>(0.3247)    | 0.3617<br>(0.2610)    |
| Social Science                | -0.2249<br>(0.3465)  | -0.1937<br>(0.3529)  | 0.2551<br>(0.3932)  | -0.0963<br>(0.3923)    | -0.0525<br>(0.3865)   | -0.0195<br>(0.3466)   |
| Humanities                    | -0.4401<br>(0.3319)  | -0.3258<br>(0.3495)  | 0.6005<br>(0.5579)  | -0.2461<br>(0.4400)    | -0.1947<br>(0.4377)   | -0.2373<br>(0.3408)   |
| Testosterone                  | 0.0475<br>(0.6249)   | 0.2638<br>(0.8050)   | -0.6886<br>(0.5902) | -0.5542***<br>(0.2028) | -0.4808**<br>(0.2404) | -0.1090<br>(0.1585)   |
| Estradiol                     | -0.1281<br>(0.2394)  | -0.0651<br>(0.2851)  | 0.1713<br>(0.1657)  | 0.0192<br>(0.1726)     | 0.0045<br>(0.1764)    | 0.1298<br>(0.1362)    |
| Progesterone                  | 0.1493<br>(0.1635)   | 0.1400<br>(0.1943)   | 0.0059<br>(0.1030)  | 0.2473<br>(0.2843)     | 0.2976<br>(0.2874)    | 0.2168<br>(0.1996)    |
| Cortisol                      | 0.4290*<br>(0.2190)  | 0.4220*<br>(0.2137)  | 0.2133<br>(0.1788)  | 0.2339<br>(0.1448)     | 0.2106<br>(0.2479)    | 0.0267<br>(0.1003)    |
| Contraceptives                | -0.0760<br>(0.4050)  | 1.2296<br>(1.1333)   | 0.0558<br>(0.3075)  |                        |                       |                       |
| Contracept. x Testost.        |                      | -0.8435<br>(1.0663)  |                     |                        |                       |                       |
| Contracept. x Estradiol       |                      | -0.3076<br>(0.3576)  |                     |                        |                       |                       |
| Contracept. x Progest.        |                      | 0.2202<br>(0.2513)   |                     |                        |                       |                       |
| Lunch today x Testost.        |                      |                      |                     |                        | -0.1461<br>(0.2412)   |                       |
| Lunch today x Cort.           |                      |                      |                     |                        | -0.0248<br>(0.2873)   |                       |
| <i>Number of Observations</i> | 70                   | 70                   | 79                  | 102                    | 102                   | 110                   |
| R <sup>2</sup>                | 0.2095               | 0.2341               | 0.2007              | 0.1467                 | 0.1624                | 0.1874                |

Robust standard errors in parentheses; Significance levels: \*10%; \*\* 5%; \*\*\* 1%.

correction. We also replicate our null findings for hormones in the loss domain using analogous specifications L3F and L3M for our female and male subsamples, respectively.

Our positive finding that testosterone is significantly negatively correlated with testosterone in males is robust to adding session fixed effects, the use of ordered probit instead of OLS, the addition of further demographic controls such as sexual preferences, BMI,

number of siblings etc., controls for the quality of saliva or dietary preferences, or dropping demographic controls in specification G3M (not reported).

Controlling linearly for hormonal contraceptives in the female subsample may not be most appropriate in our setting. The use of hormonal contraceptives may introduce biases in salivary sex hormones. As mentioned above, all hormonal contraceptives contain progestin, a synthetic version of progesterone. Some hormonal contraceptives contain estradiol. Moreover, Alexander et al. (1990) report that users of oral contraceptives exhibit higher blood plasma concentrations of testosterone. But Wiegratz et al. (1995) and Coenen et al. (1996) report that women on certain hormonal contraceptives have lower levels of plasma testosterone, and a similar finding was reported by Schultheiss et al. (2003) for salivary testosterone and estradiol. Testosterone is thought to be positively associated with aggression although no consistent correlation has been reported for women (Dabbs and Hargrove, 1997). Could it be that our findings and null findings on the correlations of salivary sex hormones with risk aversion are driven or masked by the use of hormonal contraceptives? We could analyze women on hormonal contraceptives separately from other women but the sizes of the subsamples are rather small. Instead, we interact the dummy for the use of hormonal contraceptives with testosterone, estradiol, and progesterone, respectively, and include them in specification G4F analogous to G3F in Table 11. The coefficient for the salivary hormone now measures the effect of that hormone when the dummy for the use of hormonal contraceptives is zero. That is, we can check whether we find the same effect of hormones in females not taking hormonal contraceptives. As we can see, none of the salivary hormones is significant except cortisol which is marginally significant ( $p = 0.053$ ) and positive.

In Appendix B we show that salivary testosterone and cortisol are significantly negatively effected by the amount of time past lunch in males (Table 21, specifications TM and CM). Our positive finding for cortisol for gains in the full sample (Table 8, specification G3) does not reappear in the male subsample (Table 11, specification G3M). Could this be due to the fact that the quality of our salivary cortisol measure for males is too much “contaminated” by the amount of time past lunch? To investigate this issue, we create interaction terms “Lunch today  $\times$  Cortisol” and “Lunch today  $\times$  Testosterone”, and include them into specification G4M analogous to specification G3M. When the male skipped lunch, then these terms are zero. Thus, the coefficient for cortisol (resp. testosterone) now measures the effect of cortisol (resp. testosterone) for males who skipped lunch. We see in specification G4M that cortisol is still insignificant.

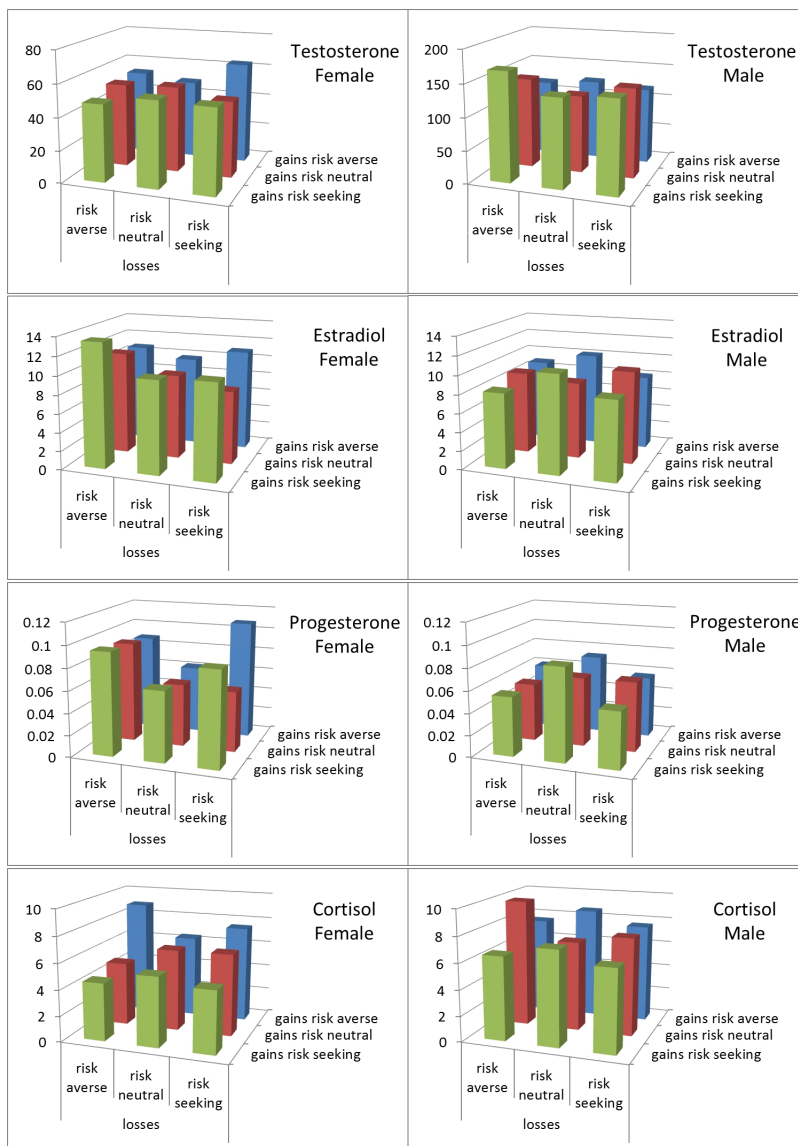
In Figure 7 we graph for each hormone average salivary hormone levels of subjects classified into risk attitudes both in the gain and loss domains (see Section 2.1). Subjects who display the reflection effect are subjects in the right back corner. These are subjects who are risk averse in the gain domain while being risk seeking in the loss domain. The upper two panels reveal another interesting sexual dimorphism. Females displaying the reflection effect appear to have the highest average testosterone levels among females while males displaying the reflection effect seem to have the lowest testosterone levels on average among males. Furthermore, females displaying the reflection effect seem to have



the largest progesterone levels on average.

In Table 9, we investigate these preliminary observations with logit regressions in which we regress the reflection effect on salivary hormones and demographic variables. When we analyze the female subsample separately in specification R3F, then we rediscover our findings from Figure 7. The reflection effect is significantly positively correlated with testosterone ( $p = 0.004$ ) as well progesterone ( $p = 0.002$ ) in females. This is also significant when we correct for multiple testing using Bonferroni correction. Estradiol is negative but just marginally significant ( $p = 0.092$ ) and thus insignificant using Bonferroni correction for multiple testing.

Figure 7: Salivary Hormones (ex ante) & Risk Attitudes by Gender



Again, since as mentioned above hormonal contraceptives interact with circulating levels of sex steroids, the question arises whether our positive findings on the reflection effect is driven by women on hormonal contraceptives. When we add the interaction terms in specification R4F in Table 9, we observe that the effect of testosterone and progesterone is declines slightly but it is still significant ( $p = 0.019$  for both testosterone and progesterone). This, however, is slightly above our significance threshold of %1.25 to account for multiple testing. Thus, testosterone and progesterone are just marginally significant for women who do not use hormonal contraceptives after accounting for multiple testing. Compared to specification R3F, estradiol loses its marginal significance in R4F ( $p = 0.261$ ).

No significant correlations with salivary hormones and the reflection effect are observed for males in specification R3M. This continues to hold when we control for lunch time similar to specification G4M.

With respect to accessibility, the logit specification A3F in Table 10 reveals that testosterone is significantly negatively correlated with accessibility of preferences in females ( $p = 0.044$ ). Yet, this is insignificant when adjusting for multiple testing using Bonferroni correction. Cortisol is positive but just marginally significant before adjusting for multiple testing and insignificant after Bonferroni correction. As mentioned above, hormonal contraceptives interact with circulating levels of sex steroids. Thus, the question arises whether this positive finding on testosterone is driven by women on hormonal contraceptives. When we add the interaction terms in specification A4F in Table 10, we observe that the effect size of testosterone increases (in absolute terms) with  $p = 0.049$  but this still stays insignificant when adjusting for multiple testing using Bonferroni correction.

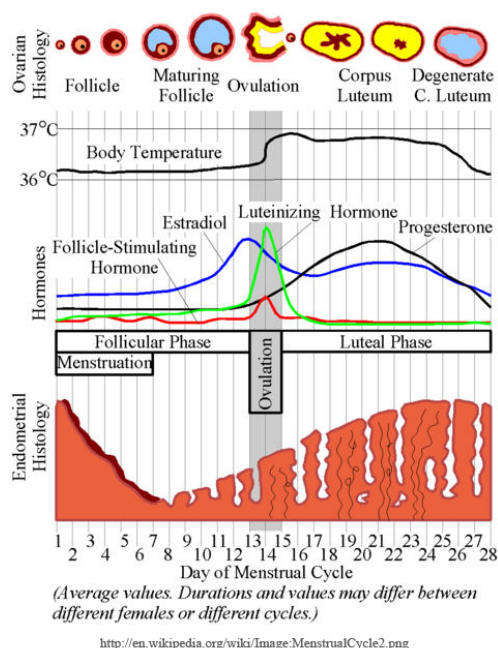
In males, estradiol is significantly negatively correlated with accessibility ( $p = 0.004$ ). This is also significant under Bonferroni correction for multiple testing. This finding is not robust to dropping demographic controls of specification A3M. But it is for instance robust to the addition of controls for dietary preferences. We summarize our observations on salivary hormones by gender as follows:

**Observation 5 (Salivary hormones by gender)** *For males, testosterone is significantly negatively correlated with risk aversion. This also holds when using Bonferroni correction to account for multiple testing. For females, no robust significant association is found for salivary hormones and risk aversion for either gains and losses. Yet, cortisol is marginally significantly positively correlated with risk aversion for gains in females. This is insignificant after Bonferroni correction for multiple testing. In females, both testosterone and progesterone are significantly positively correlated with reflection. This also holds under Bonferroni correction to account for multiple testing. The correlation is just marginally significant (insignificant when using Bonferroni correction) in females who do not use hormonal contraceptives. Testosterone is marginally significantly negatively correlated with accessibility in females. This is insignificant after Bonferroni correction for multiple testing. Estradiol is significantly negatively correlated with accessibility in males when controlling demographics. It is also significant using Bonferroni correction to*

account for multiple testing.

Apicella et al. (2008) find that risk-taking in an investment task in the gain domain is significantly positively correlated with salivary testosterone levels in men. We provide an independent replication of their results with respect to a different choice task under risk. Sapienza et al. (2009) use a similar task to ours in the gain domain. They also find a significant negative correlation between salivary testosterone concentrations and risk aversion, but this observation becomes insignificant when controlling for gender. None of the previous papers we know of study the correlation between choice under risk for *both gains and losses* and *all of salivary testosterone, estradiol, progesterone, and cortisol*.

Figure 8: Menstrual Cycle



### 3.4 Menstrual Cycle

Women differ from men in circulating levels of certain hormones, and some of those hormones change across the menstrual cycle. Estradiol, progesterone, the lutenizing hormone, and the follicular stimulating hormone all change over the menstrual cycle (see Figure 8).<sup>11</sup> Thus menstrual cycle information provides relative easy to observe within-female measures of some hormones.

<sup>11</sup>The lutenizing hormone and the follicular stimulating hormone are glycoproteins that cannot be measured in saliva.

Table 12: Menstrual Cycle Phases and Contraceptives

| Menstrual Cycle Phases  | Days         | 28-Days Stand. |      | Uniform Adj. |      | Fol. Phase Adj. |      | Expected Frequency |
|-------------------------|--------------|----------------|------|--------------|------|-----------------|------|--------------------|
|                         |              | Number         | Mean | Number       | Mean | Number          | Mean |                    |
| Menstrual Phase         | Days 1 - 5   | 17             | 0.18 | 16           | 0.17 | 17              | 0.18 | 0.14               |
| Follicular Phase        | Days 6 - 13  | 12             | 0.13 | 16           | 0.17 | 16              | 0.17 | 0.22               |
| Peri-Ovulatory Phase    | Days 14 - 15 | 6              | 0.07 | 6            | 0.07 | 5               | 0.05 | 0.05               |
| Luteal Phase            | Days 16 - 23 | 19             | 0.21 | 19           | 0.21 | 19              | 0.21 | 0.22               |
| Pre-Menstrual Phase     | Days 24 - 28 | 17             | 0.18 | 14           | 0.15 | 15              | 0.15 | 0.14               |
| Total                   |              | 71             | 0.77 | 71           | 0.77 | 71              | 0.77 | 0.77               |
| Hormonal Contraceptives |              | 21             | 0.23 | 21           | 0.23 | 21              | 0.23 | 0.23               |

From all female subjects we obtained information about their menstrual cycle. Table 12 presents the distribution across menstrual cycle phases for naturally cycling women. Women who take hormonal contraceptives do not have a natural menstrual cycle, and their circulating levels of hormones may differ from naturally cycling women.<sup>12</sup> Therefore we consider for the classification of women into menstrual cycle phases only women who *do not* take hormonal contraceptives, so called naturally cycling women.

The 28-days standardized menstrual cycle phases (third and fourth columns) follows the same definition of menstrual phases as in Chen, Katuščák, and Ozdenoren (2009). It assumes that all women follow a menstrual cycle standardized to 28 days. We distinguish the menstrual phase (days 1 to 5), the follicular phase (days 6 to 13), the peri-ovulatory phase (days 14 to 15), the luteal phase (days 16 to 23), and the premenstrual phase (days 24 to 28).

One major implicit assumption behind the standardized 28-day menstrual cycle is that *all* women follow a *menstrual cycle of exactly 28 days*. However, we find substantial variation in usual cycle length. All 72 naturally cycling women reported also their usual cycle length. The average is 29.5 days with a standard deviation of 3.24.<sup>13</sup> Further noise may be introduced through intrapersonal variability in cycle length. The length of the menstrual cycle may vary from cycle to cycle even within the same woman, and the woman can not know the exact length of her *current* menstrual cycle. Finally, there is measurement error due to imperfect recall. Self-reports may be inaccurate and this inaccuracy may depend on the day of the menstrual cycle. Menstruating women usually

<sup>12</sup>See Briggs and Briggs (1972), Kjeld et al. (1976), Wiegratz et al. (1995), Coenen et al. (1996), Spona et al. (1996), Kirschbaum, et al. (1999), Schultheiss et al. (2003), Edwards and O’Neal (2009), and Liening et al. (2010).

<sup>13</sup>Regarding the “Length Menstrual Cycle”, answers of “> 35 days” have been normalized to 37 days. Answers “< 25 days” have been normalized to 24 days. Our estimations are robust to small changes of those upper and lower bounds.

know that they are menstruating while later in the cycle women may not remember exactly their first day of their menstrual cycle. This raises the question whether estimation results will be robust to slight changes in the definitions of the menstrual phases.

Fortunately, we can use the collected information on the usual length of the menstrual cycle to construct more individualized menstrual cycle measures as in Pearson and Schipper (2011). *Individualized phases* are constructed in two ways: uniformly adjusted phases and follicular adjusted phases.

*Uniformly Adjusted Phases:* We uniformly adjust the phases by the individual length of the menstrual cycle. Let

$$x_i := \frac{\text{Subject } i\text{'s number of days since the first day of the last menstruation period}}{\text{Length of subject } i\text{'s typical menstruation cycle}}.$$

We define the female subject  $i$  to be in the

1. *Uniformly Adjusted Menstrual Phase* if and only if  $x_i \leq \frac{5.5}{28}$ ,
2. *Uniformly Adjusted Follicular Phase* if and only if  $\frac{5.5}{28} < x_i \leq \frac{13.5}{28}$ ,
3. *Uniformly Adjusted Peri-ovulatory Phase* if and only if  $\frac{13.5}{28} < x_i \leq \frac{16.5}{28}$ ,
4. *Uniformly Adjusted Luteal Phase* if and only if  $\frac{16.5}{28} < x_i \leq \frac{23.5}{28}$ ,
5. *Uniformly Adjusted Premenstrual Phase* if and only if  $\frac{23.5}{28} < x_i$ .

*Follicular Adjusted Phases:* Hampson and Young (2008) write “The length of the luteal phase is relatively fixed at 13 to 15 days. Therefore, most of the variation in cycle length from woman to woman is attributable to differences in the length of the follicular phase.” Thus, we consider adjusting the length of the follicular phase only. We start by redefining recursively the last three phases starting with the last phase. Let  $y_i$  be subject  $i$ 's the number of days since the first day of the last menstrual cycle, and  $d_i$  the average duration of  $i$ 's menstrual cycles. Female subject  $i$  is in the

1. *Follicular Adjusted Premenstrual Phase* if and only if  $y_i > d_i - 5$ ,
2. *Follicular Adjusted Luteal Phase* if and only if  $y_i > d_i - 13$  and  $i$  is not in the Follicular Adjusted Premenstrual Phase,
3. *Follicular Adjusted Peri-ovulatory Phase* if and only if  $y_i > d_i - 16$  and  $i$  is not in the Follicular Adjusted Premenstrual Phase or the Follicular Adjusted Luteal Phase.

Next, female subject  $i$  is in the

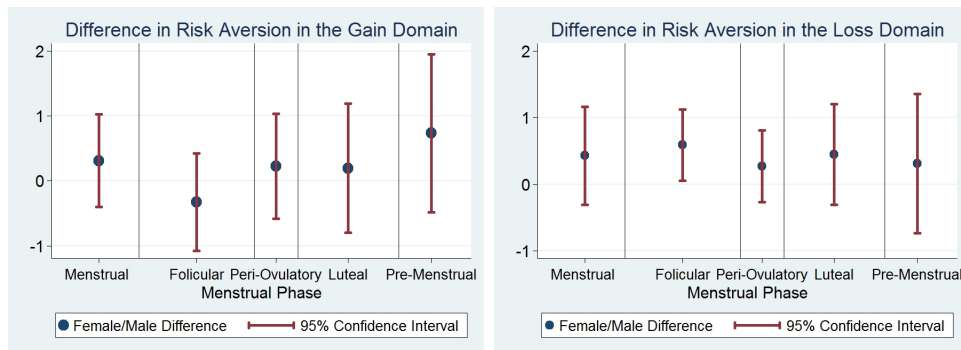
4. *Follicular Adjusted Menstrual Phase* if and only if  $i$  is in the Menstrual Phase.

Finally, female subject  $i$  is in the

5. *Follicular Adjusted Follicular Phase* if and only if  $i$  is not in the Follicular Adjusted Menstrual Phase, Follicular Adjusted Peri-ovulatory Phase, Follicular Adjusted Luteal Phase or Follicular Adjusted Premenstrual Phase.

Table 7, columns 5 to 8, show the empirical distribution of uniformly adjusted and follicular adjusted menstrual cycle phases in our naturally cycling females, respectively. The distributions differ slightly. For comparison, we report in the last column of Table 7 the expected frequency of natural menstrual cycle phases assuming an uniform probability to participate in the experiment at any day of a 28 days standard menstrual cycle conditional on 23% of the female population taking hormonal contraceptives.

Figure 9: Female/Male Difference in Risk Aversion over the Menstrual Cycle



In Figure 9 we plot the female/male differences in the number of choices of option A for the gain and the loss domain, respectively. The left panel for the gain domain seem to suggest that women become relatively less risk averse towards the midcycle when fecundity is highest. But the 95% confidence intervals make also clear that noise is quite high. No such cyclic tendency is observed for losses.

We believe that a cyclic tendency with respect to risk aversion for gains but not for losses seems quite intuitive. With regards to gains, females may behave more risky during their fecund period. Risky behavior may lead to a higher probability of conception, genetic diversity and higher quality offspring through extrapair mating. This may be especially successful in monogamous societies where some females must be matched with substandard males. Thus females with risky behavior near ovulation may have a higher reproductive success. On one hand, extrapair mating is risky because if discovered it is punished severely in most societies and may lead to a loss of the long term mating partner who supports child rearing. There is some evidence for greater mate guarding near ovulation (see Gangestad, Thorndill, and Garver, 2002, and Haselton and Gangestad, 2006), which may be a long-term male mate's best response to riskier behavior of the female during her fecund window and may in turn require more risky behavior of females

to escape the guard. On the other hand, males of higher genetic quality tend to have poorer parental qualities (Gangestad and Simpson, 2000). To maximize the quality of the genetic endowment, a female should have the highest propensity for extrapair mating during her fecund period. Bressan and Stranieri (2008) show that partnered women favor single men with more masculine features during their fecund phase, while they prefer attached men during their low-fecundity phase.<sup>14</sup> Wilcox et al. (2004) show that the frequency of intercourse increases during the fecund period.<sup>15</sup>

Clearly, this evolutionary explanation invites further questions. For instance, why should females be more risk averse than males in the first place? An answer may be given based on the “sperm-is-cheap-eggs-are-costly” hypothesis (Bateman, 1948, Trivers, 1972). In principle, a male has abundant sperm until old age while the number of fecund windows in a woman’s life is relatively small (about 400). Since the total number of offspring produced by all males must equal to the number of offspring of all females, the females become the limiting resource. Competition for female mating partners among males is similar to a winner-take-all contest in which the most successful males can mate with a larger number of females. For winner-take-all games, Dekel and Scotchmer (1999) show conditions under which risk-taking behavior emerges in an evolutionary process. An alternative answer may be based on an evolutionary model by Robson (1996) in which he shows that some males may gamble and females behave strictly risk averse.<sup>16</sup>

In Table 13 we report coefficients and standard errors for regressions on dummies for follicular adjusted menstrual phases. Similar results obtain when using the other two definitions of menstrual cycle phases (not reported). The OLS-specification G5 uses the number of choices of option A in the gain domain as the dependent variable, while L5 is analogous for the loss domain. Finally, the logit regressions R5 and A5 analyze reflection and accessibility of preferences, respectively. For all specifications, we suppress in the report coefficients and standard errors for all demographic variables. We reject the hypothesis that women are more risk averse in the gain domain during the fecund phase of their cycle. G5 reveals no significant correlation between menstrual cycle phases and risk aversion in the gain domain. For L5, the follicular phase is positive and significant for risk aversion in the loss domain ( $p = 0.031$ ). Note however, that our analysis involves now multiple testing of five menstrual cycle phases. To account for this problem, we can use Bonferroni correction. If the desired significance level is 5%, the the Bonferroni corrected

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<sup>14</sup>For related evidence, see Gangestad, Thornhill, and Garver-Apgar (2006), Penton-Voak et al. (1999), and Penton-Voak and Perrett (2000).

<sup>15</sup>In this latter study, evidence is provided only for women in a stable relationship. The study is silent on whether intercourse is with the long-term mating partner or with an extra mate.

<sup>16</sup>The hypothesis that women may behave more risk-taking during their fecund phase of their cycle seems to contradict Bröder and Hohmann (2003), who claim that women avoid taking risks near ovulation in order to reduce the chance of being raped. Yet, their experiment did not discriminate between risks in the gain and loss domain but such a distinction may clearly matter with prospect theory in mind (Kahneman and Tversky, 1979). Moreover, the authors could not replicate their results (private communication by Arndt Bröder). Finally, Fessler (2003) argues that rape is not less frequent during the ovulatory phase.

significance threshold is 1%. Thus, the follicular phases is not even marginally significant when adjusted for multiple testing.

Table 13: Menstrual Cycle Phases

|                               | (G5)                | (L5)                 | (R5)                | (A5)                  |
|-------------------------------|---------------------|----------------------|---------------------|-----------------------|
| Fol. Adj. Menstrual Phase     | 0.3129<br>(0.3605)  | 0.4270<br>(0.3726)   | -0.2876<br>(0.8911) | -1.2265*<br>(0.7040)  |
| Fol. Adj. Follicular Phase    | -0.3228<br>(0.3835) | 0.5857**<br>(0.2697) | -0.1200<br>(0.8066) | -1.2850*<br>(0.6781)  |
| Fol. Adj. Peri-ovular Phase   | 0.2458<br>(0.4286)  | 0.2668<br>(0.2704)   |                     | -2.7258**<br>(1.1291) |
| Fol. Adj. Luteal Phase        | 0.1231<br>(0.5239)  | 0.4753<br>(0.4031)   |                     | -1.6062**<br>(0.6811) |
| Fol. Adj. Premenstrual Phase  | 0.7416<br>(0.6142)  | 0.3096<br>(0.5269)   | 0.5307<br>(0.8172)  | -1.1294<br>(0.8244)   |
| Contraceptives                | -0.1071<br>(0.2450) | 0.4035*<br>(0.2250)  | -0.5051<br>(0.8522) | 0.0732<br>(0.7368)    |
| <i>Number of Observations</i> | 173                 | 190                  | 171                 | 196                   |
| <i>R<sup>2</sup></i>          | 0.0758              | 0.1087               |                     |                       |

Robust standard errors in parentheses; Significance levels: \*10%; \*\* 5%; \*\*\* 1%.

We suppress from the report coefficients for age, Asian, other ethnicity, GPA, mathematics, science & engin., economics, social science, and humanities.

In the logit specification R5, failure of reflection is predicted perfectly when the (accessible) women is in the peri-ovulatory or in the luteal phase. With regard to consistency, women in the peri-ovulatory and luteal phase are significantly less accessible than white males ( $p = 0.016$  and  $p = 0.018$  for the peri-ovulatory and luteal phase, respectively). When we Bonferroni correct these values for multiple testing, both phases are marginally significant. Nevertheless we find this result surprising in light of our finding on hormonal contraceptives. Recall that in specification A2, Table 6, we observed that women on hormonal contraceptives are significantly more accessible than white males. One explanations we put forward was that all hormonal contraceptives contain progestines, synthetic versions of progesterone. Progesterone prepare the women for pregnancy and increases after ovulation. In principle a women could be with child after ovulation and a higher propensity to make consistent choices may confer an evolutionary advantage. In naturally cycling women that did not conceive during the cycle, progesterone peaks in the luteal phase (see Figure 8). Following this explanations, we would expect women in the luteal phase to be more consistent. Yet, we see the opposite even if the correlation is just marginally significant when Bonferroni corrected. We conclude that our observation on hormonal contraceptives may be rather due to the selection effect than through the progesterone hypothesis. Women in college are in a sexually active age. Thus, deciding to use hormonal contraceptives to prevent an unwanted pregnancy in college out of wedlock may be an expression of consistent choice under risk in a specific real-life context. Note that this would be also consistent with the fact that we did not find any significant correlation between progesterone and accessibility in specifications A3F and A4F in



Table 10.

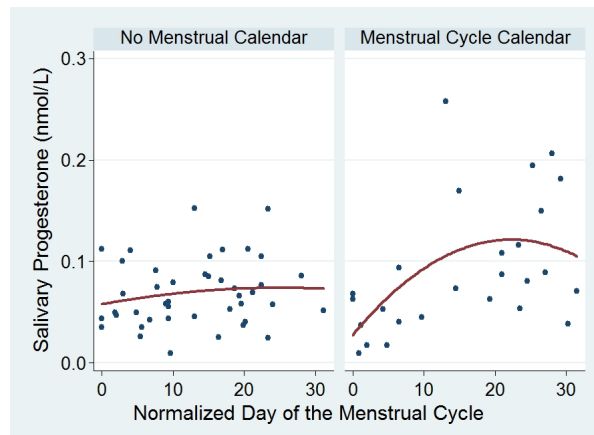
While this explanation allows us to select among the competing explanations for our result on the use of hormonal contraceptives, we still miss an explanation for why we find the marginally significant negative correlation between the peri-ovulatory and luteal phase and accessibility. One explanation may be simply measurement error. As mentioned before, self-reported menstrual cycle information may be noisy due to imperfect recall or the uncertainty that nature creates about a woman’s fecundity. It could be that most of the women assigned to the peri-ovulatory and luteal phases are actually in the peri-ovulatory phase when fecundity is highest. In this phase, inconsistent behavior may yield an evolutionary advantage at least for small stakes as it may raise the attention of potential mates and thus increases the probability of conception. Alternatively, being indifferent among a wide range of options may mitigate conflicts.

We summarize these observations as follows:

**Observation 6 (Menstrual Cycle)** *We do not find any significant correlation between menstrual cycle phases and risk preferences for gains or losses. However, preferences of females in the peri-ovulatory and luteal phases are marginally significantly less accessible than white males when Bonferroni corrections are made for multiple testing.*

**Observation 7 (Hormonal Contraceptives and “Consistency” Revisited)** *Our previous finding that females on hormonal contraceptives are significantly more “consistent” is likely to be due to a selection effect rather than progestins contained in hormonal contraceptives. This conclusion is based on the fact that preferences of females in the peri-ovulatory and luteal phases (i.e., phases with increased progesterone levels) are marginally significantly less accessible and we do not find any significant correlation between accessibility and salivary progesterone in females.*

Figure 10: Accuracy of Self-Reported Menstrual Cycle Information by Calendar Keeping



Since progesterone changes predictably over the menstrual cycle (see Figure 8), we could try to use our salivary hormone measurements to investigate the accuracy of self-reported menstrual cycle information. Some women keep menstrual cycle calendars. Presumably their self-reported menstrual cycle information should be more precise although the decision to keep a menstrual cycle calendar may be endogenous to the woman’s regularity of her cycle. In Figure 10 we present scatter plots of progesterone levels over days in the menstrual cycles of naturally cycling females by whether they keep a menstrual calendar or not. While we are able to fit a quadratic regression that peaks in the luteal phase for women who keep a menstrual cycle calendar, no such association is visible in the plot for women who do not keep a menstrual cycle calendar. Although these pictures involve between-comparisons of females instead of a within-comparison, we believe they still illustrate the noisiness of self-reported menstrual cycle information especially by women who do not keep a menstrual cycle calendar.

Table 14: Digit Ratio

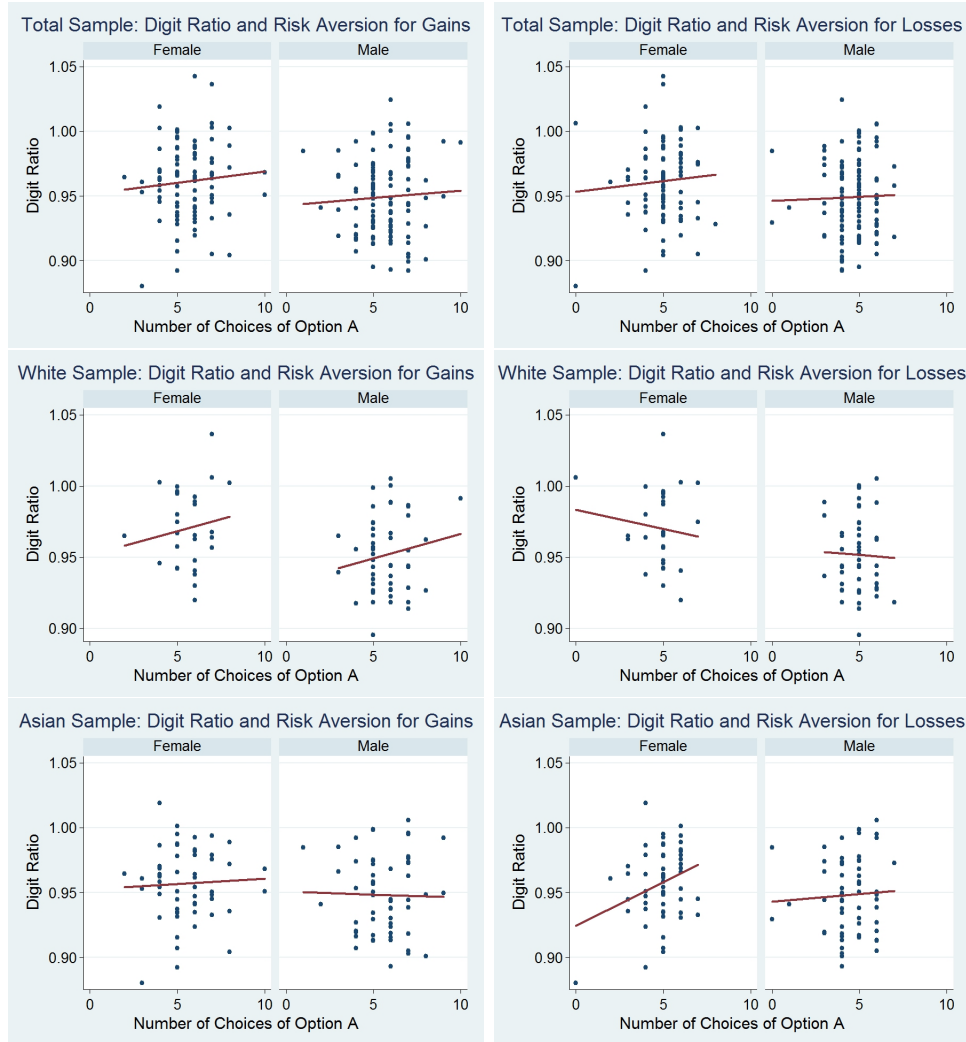
| Ethnicity   | Females |           | Males |           |
|-------------|---------|-----------|-------|-----------|
|             | Mean    | Std. Dev. | Mean  | Std. Dev. |
| White       | 0.970   | 0.0275    | 0.952 | 0.0267    |
| Asian       | 0.957   | 0.0274    | 0.948 | 0.0296    |
| Other Ethn. | 0.968   | 0.0384    | 0.944 | 0.0360    |
| Total       | 0.962   | 0.0294    | 0.949 | 0.0290    |

### 3.5 Digit Ratio

We scanned each subject’s right hand from which measured and calculated the digit ratio (2D:4D), the ratio between the lengthes of the pointer to the ring finger. The summary statistics are presented in Table 14. As it is well-known in the literature, females have on average a larger digit ratio than males. For one subject we accidentally scanned the left hand instead the right hand. We measured the fingers nevertheless and include this observation in our analysis. Our results do not change when we drop this subject.

In Figure 11 we present scatter plots for the correlation between the digit ratio and the number of choices of option A by gender for both gains and losses. The upper two panels are for the full sample by gender. We also fit linear regressions. These regression lines indicate a positive relationship between digit ratio and risk aversion. This appears to be more pronounced in females than males. However, when we try to corroborate these preliminary observations with multivariate regressions for subjects with accessible preferences, we do not find significant results. In Table 15 we present results from specifications in which we regressed the number of choices of option A by accessible subjects on a “minimal” set of demographic variables and the digit ratio using OLS. We

Figure 11: Digit Ratio and Risk Aversion by Gender and Ethnicity



find a null result when we consider the entire sample in specification GDR ( $p = 0.280$ ). We also find null results when we analyze females and males separately in specifications GDRF ( $p = 0.466$ ) and GDRM ( $p = 0.451$ ), respectively. For the loss domain, we obtain similar null results (LDR, LDRF, and LDRM, respectively). Null results are also observed for logit specifications on reflection and accessibility in Table 16.

Note that in addition to age we control for race in all specifications of Tables 15 and 16. It is known in the existing literature that a digit ratio may have a significant effect on risk taking in a homogeneous white population while such effect may not be present in a racially more mixed population (see Apicella et al., 2008 versus Dreber and Hoffman, 2007, and Garbarino et al., 2011). That's why we analyze our white subpopulation separately. Table 17 presents null results for risk aversion in both the loss and gain domain for whites,

Table 15: Full Sample: Digit Ratio and Risk Aversion

|                               | (GDR)               | (GDRF)               | (GDRM)              | (LDR)               | (LDRF)               | (LDRM)                |
|-------------------------------|---------------------|----------------------|---------------------|---------------------|----------------------|-----------------------|
| Asian                         | -0.2273<br>(0.2056) | -0.2688<br>(0.3069)  | -0.2049<br>(0.2778) | -0.2377<br>(0.1761) | 0.0434<br>(0.2909)   | -0.4071*<br>(0.2085)  |
| Other                         | 0.3809<br>(0.2786)  | 0.6132**<br>(0.2885) | 0.1633<br>(0.4564)  | 0.0897<br>(0.2538)  | 0.8449**<br>(0.3668) | -0.6053**<br>(0.2913) |
| Female                        | -0.1053<br>(0.2188) |                      |                     | 0.2894<br>(0.1896)  |                      |                       |
| Digit Ratio                   | 3.7301<br>(3.4388)  | 3.6784<br>(5.0172)   | 3.5303<br>(4.6691)  | 2.0634<br>(3.7882)  | 3.7833<br>(7.3638)   | 0.8893<br>(3.4573)    |
| <i>Number of Observations</i> | 180                 | 74                   | 106                 | 197                 | 83                   | 114                   |
| R <sup>2</sup>                | 0.0294              | 0.0662               | 0.0139              | 0.0430              | 0.0562               | 0.0994                |

Robust standard errors in parentheses; Significance levels: \*10%; \*\* 5%; \*\*\* 1%.  
We suppress from the report the coefficient for age.

Table 16: Full Sample: Digit Ratio, Reflection, and Accessibility

|                               | (RDR)                | (RDRF)              | (RDRM)                | (ADR)                  | (ADRF)              | (ADRM)              |
|-------------------------------|----------------------|---------------------|-----------------------|------------------------|---------------------|---------------------|
| Asian                         | 0.1661<br>(0.4485)   | -0.4627<br>(0.7749) | 0.5435<br>(0.5670)    | -0.5157<br>(0.4605)    | -0.9227<br>(0.5676) | 0.0927<br>(0.8120)  |
| Other                         | 1.1794**<br>(0.5799) | -0.4881<br>(1.1451) | 2.2263***<br>(0.7968) | -0.4086<br>(0.6662)    | -0.0667<br>(0.8705) | -0.9683<br>(0.9303) |
| Female                        | -0.7111<br>(0.4589)  |                     |                       | -1.2012***<br>(0.4256) |                     |                     |
| Digit Ratio                   | -8.9920<br>(6.3537)  | 1.2618<br>(8.6220)  | -12.7860<br>(8.2029)  | 3.7444<br>(7.0138)     | -0.7171<br>(9.7705) | 9.0809<br>(10.0565) |
| <i>Number of Observations</i> | 178                  | 72                  | 106                   | 208                    | 93                  | 115                 |
| R <sup>2</sup>                |                      |                     |                       |                        |                     |                     |

Robust standard errors in parentheses; Significance levels: \*10%; \*\* 5%; \*\*\* 1%.  
We suppress from the report the coefficient for age.

while Table 18 does the same for reflection and accessibility. In latter table, we observe in specification ADRWF that the digit ratio is negatively correlated with accessibility in white women but this result is just marginally significant ( $p = 0.096$ ). Table 19 reports null results on the digit ratio and risk aversion for Asians. Finally, in Table 20 we observe that reflection is significantly negatively correlated with the digit ratio in Asians ( $p = 0.021$  in the logit specification RDRA) and in asian males ( $p = 0.024$  in the logit specification RDRAM). No positive results are obtained for accessibility in the asian subpopulation.

Implicitly our analysis so far involved multiple comparisons of four groups: white males, white females, asian males, and asian females. Moreover, we consider risk aversion for gains and losses as well as reflection and accessibility. There is a relatively large chance that we find some “significant” correlation between a dependent variable and the digit ratio that may be based on an erroneous inference. Again, we employ our conservative correction provided by the Bonferroni method. If the desired significance level for the

Table 17: White Sample: Digit Ratio and Risk Aversion

|                               | (GDRW)              | (GDRWF)            | (GDRWM)            | (LDRW)              | (LDRWF)              | (LDRWM)             |
|-------------------------------|---------------------|--------------------|--------------------|---------------------|----------------------|---------------------|
| Female                        | -0.1677<br>(0.2999) |                    |                    | -0.0950<br>(0.2703) |                      |                     |
| Digit Ratio                   | 6.9718<br>(4.8954)  | 3.5892<br>(7.6608) | 8.9771<br>(6.4872) | -3.3148<br>(4.8677) | -6.9426<br>(10.5702) | -1.2983<br>(4.6173) |
| <i>Number of Observations</i> | 73                  | 25                 | 48                 | 78                  | 27                   | 51                  |
| R <sup>2</sup>                | 0.0735              | 0.0087             | 0.1104             | 0.0178              | 0.0465               | 0.0070              |

Robust standard errors in parentheses; Significance levels: \*10%; \*\* 5%; \*\*\* 1%.  
We suppress from the report the coefficient for age.

Table 18: White Sample: Digit Ratio, Reflection, and Accessibility

|                               | (RDRW)               | (RDRWF)              | (RDRWM)              | (ADRW)               | (ADRWF)                | (ADRWM)              |
|-------------------------------|----------------------|----------------------|----------------------|----------------------|------------------------|----------------------|
| Female                        | 0.1736<br>(0.6967)   |                      |                      | -0.9300<br>(0.8225)  |                        |                      |
| Digit Ratio                   | -1.8849<br>(11.4012) | -0.5890<br>(17.6400) | -1.6898<br>(14.6309) | -8.8378<br>(13.4647) | -25.4620*<br>(15.2823) | 11.5672<br>(19.3701) |
| <i>Number of Observations</i> | 73                   | 25                   | 48                   | 79                   | 28                     | 51                   |
| R <sup>2</sup>                |                      |                      |                      |                      |                        |                      |

Robust standard errors in parentheses; Significance levels: \*10%; \*\* 5%; \*\*\* 1%.  
We suppress from the report the coefficient for age.

family of race-gender pairs is 5%, the Bonferroni corrected significance level for each digit ratio coefficient should be 1.25% (since there are four such groups). Yet, all of our “significant” results have  $p$ -values strictly above this threshold. In fact, no correlation is even marginally significant. Additional observations may yield sharper results.

Table 19: Asian Sample: Digit Ratio and Risk Aversion

|                               | (GDRA)              | (GDRAF)            | (GDRAM)            | (LDRA)             | (LDRAF)             | (LDRAM)            |
|-------------------------------|---------------------|--------------------|--------------------|--------------------|---------------------|--------------------|
| Female                        | -0.2031<br>(0.3332) |                    |                    | 0.3573<br>(0.2581) |                     |                    |
| Digit Ratio                   | 3.3858<br>(5.2584)  | 6.1738<br>(7.3200) | 1.4777<br>(7.2134) | 7.4755<br>(5.4218) | 13.0222<br>(9.4388) | 3.4792<br>(5.4793) |
| <i>Number of Observations</i> | 98                  | 44                 | 54                 | 109                | 51                  | 58                 |
| R <sup>2</sup>                | 0.0212              | 0.0227             | 0.0232             | 0.0708             | 0.0918              | 0.1100             |

Robust standard errors in parentheses; Significance levels: \*10%; \*\* 5%; \*\*\* 1%.  
We suppress from the report the coefficient for age.

We subject the null results to various robustness checks such as using ordered logit or ordered probit models instead OLS, probit instead logit, adding further controls, dropping observations with fingers that were difficult to measure or who reported to have some previously fractured fingers, etc. The results remain qualitatively unchanged.

Table 20: Asian Sample: Digit Ratio, Reflection, and Accessibility

|                               | (RDRA)                 | (RDRAF)            | (RDRAM)                 | (ADRA)                 | (ADRAF)             | (ADRAM)             |
|-------------------------------|------------------------|--------------------|-------------------------|------------------------|---------------------|---------------------|
| Female                        | -0.9746<br>(0.6218)    |                    |                         | -1.6702***<br>(0.6382) |                     |                     |
| Digit Ratio                   | -18.7626**<br>(8.1221) | 0.5051<br>(8.0056) | -25.2583**<br>(11.1675) | 8.9660<br>(8.9954)     | 9.3517<br>(10.6538) | 7.7595<br>(16.8540) |
| <i>Number of Observations</i> | 96                     | 42                 | 54                      | 116                    | 58                  | 58                  |
| <i>R<sup>2</sup></i>          |                        |                    |                         |                        |                     |                     |

Robust standard errors in parentheses; Significance levels: \*10%; \*\* 5%; \*\*\* 1%.  
We suppress from the report the coefficient for age.

We summarize our findings on the digit ratio as follows:

**Observation 8 (Digit Ratio)** *No significant correlation between the digit ratio and risk preferences are observed in the full sample, Asians, Whites, asian males, asian females, white males, and white females. No significant correlations between the digit ratio and accessibility is observed except in Asians and asian males. Yet, these observations become insignificant when we adjust for multiple testing using Bonferroni correction.*

Our null-results are consistent with some of the existing literature. We replicate null-results for gains with a racially mixed sample of males by Apicella et al. (2008) and extend it to losses as well as a female sample and mixed samples. Our results are in contrast to finding for homogeneous white populations for which both Dreber and Hoffman (2007) and Garbarino et al. (2011) reported a positive correlation between 2D:4D and risk aversion using a different task to measure risk aversion.

Using a homogeneous Caucasian sample and a Holt-Laury lottery task, Brañas Garza and Rustichini (2011) report a significant negative correlation between the digit ratio and risk aversion for females and an insignificant positive correlation between risk aversion and the digit ratio for males. Yet, their results also show that this depends on the task to measure risk aversion employed because they find an insignificant correlation and significant correlation for females and males, respectively, using another lottery choice task. However, the focus of their study is on whether cognitive ability may mediate the effect of 2D:4D on risk aversion. It is known from prior literature that there is a positive correlation between cognitive ability and risk-taking (e.g. Dohmen et al., 2009). Using mediation analysis, Brañas Garza and Rustichini (2011) report that for males the digit ratio has both a direct effect on risk aversion as well as an indirect effect on risk aversion via cognitive ability. Mediation analysis involves a series of regressions. In this case, they regress (1) risk aversion on the digit ratio, (2) cognitive ability on the digit ratio, and (3) risk aversion on both the digit ratio and reasoning ability (always using a regression constant). Brañas Garza and Rustichini (2011) use a Raven Progressive Matrix Task to measure cognitive ability. Using our data, we can try to replicate their finding in an ethnically mixed sample using GPA as a proxy for cognitive reasoning ability. The GPA (grade point average) is a measure of academic performance in college. We

obtain insignificant coefficients in all regressions both for gains and losses except when we regress GPA on the digit ratio (not reported). The digit ratio is significantly positively correlated with GPA in males. This is in contrast to Brañas Garza and Rustichini (2011) who find a significant negative correlation between their measure of cognitive ability and the digit ratio in males and only an insignificant positive association in females. When analyzing the asian male subsample separately, we make observations analogous to the full male sample. No significant correlations are observed for the white male and female subsamples and the asian female subsample.<sup>17</sup> We are unable to replicate Brañas Garza and Rustichini (2011) results in our sample using GPA as a proxy of cognitive ability.

## 4 Conclusions

We provide a comprehensive study of correlations between choice under risk in both the gain and loss domains and measures of circulating levels of steroids as well as prenatal exposure to testosterone and estradiol. We can draw several lessons: First, if there is an effect of sex hormones on risk attitudes, the effect is small. This may not be surprising given the literature on gender differences in risk attitudes. Most robust is the negative correlation between testosterone and risk aversion in men for the gain domain. No such correlation appears in women only. For women we find a marginal significant positive correlation between cortisol and risk aversion for gains.

Second, sex hormones cannot explain all of the gender differences in risk aversion. Quite to the contrary, we find that sex hormones jointly may counter an opposing “hormone-controlled” gender effect. While a number but not all laboratory studies find women to behave more risk averse than men on average, Eckel and Grossman (2008a) also mention that “(s)tudies with contextual frames show less consistent results.” Perhaps the lack of consistency is due to the strength of this opposing “hormone-controlled” gender effect that may differ by context. Further studies of how the effect of sex hormones on choice under risk may vary by context are warranted. For instance, in first-price auctions with symmetric independent private values, Schipper (2012) finds no effect of testosterone on bidding even though such an effect should be expected if bidding is affected by risk aversion. Yet, he finds a significant positive effect progesterone on bidding. In the current analysis we observe that testosterone is negatively correlated with risk aversion in the Holt-Laury task for gains. Taken together, these findings suggests that risk aversion may not play a large role for bidding above risk-neutral Nash equilibrium in first-price auctions with symmetric independent private values.

Third, it is worthwhile to study regularities in the accessibility of preferences. We find that preferences of females are on average less accessible. But we also find that preferences of females on hormonal contraceptives are on average more accessible. One reason (among others) for this fact could be that women on hormonal contraceptives are

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<sup>17</sup>Details are available from the author on request but can also be reproduced using the Stata do file and data sets available from <http://www.econ.ucdavis.edu/faculty/schipper/>.

on average more likely to have “consistent” preferences. We suggest that this is due to a selection effect rather than the effect of progestins contained in hormonal contraceptives. Interestingly, we also find that salivary testosterone and salivary estradiol are negatively correlated with accessibility in females and males, respectively.

Several methodological conclusions can be drawn both for experimental economics and for endocrinological economics. First, given that a theory of how hormones affect economic behavior does not exist and that there are many possible biological measures, it is important to be aware of the trade-off between false positives and false negatives. When multiple measures are taken, all of them (not just the significant ones) should be reported and statistical inference needs to be corrected for multiple testing in order to minimize false positives. Yet, minimizing false positives may leave us exposed to false negatives, and sometimes a prudent experimenter may worry more about false negatives than about false positives. An instance is perhaps our finding on cortisol. Any experimental economist who experiments with a task in which behavior is sensitive to risk attitudes should be aware of potential session effects when sessions are conducted both in the morning and afternoon or before and during exam times. This is because we find that salivary cortisol is positively correlated with risk aversion in the gain domain. Cortisol follows a circadian cycle. It is usually higher in the morning and then falls in the afternoon. It is also affected by stress such as exams etc. Thus, a careful experimenter should control for session effects when experimenting with tasks in which behavior is sensitive to risk preferences.

Second, collecting saliva from subjects for assay of hormones makes economic experiments more complex. It is very important that a careful protocol is followed in terms of timing of experimental tasks and saliva collection, storage, and assay. Moreover, researchers should collect information (see Appendices B and D) that may affect the salivary hormones in order to assess the quality of their collected salivary hormones and conduct robustness checks.

Third, we believe that self-reported menstrual cycle information and the digit ratio suffer from measurement errors. If menstrual cycle information is to be used in an experiment, we would suggest to ask subjects to keep a menstrual calendar and follow it for several months to measure both the likely time of ovulation within the menstrual cycle of interest as well as the general (ir)regularity of the subject’s cycles. For the digit ratio, if there is any effect, then demonstrating it robustly will require large racially homogenous samples (typically larger samples than used in experimental economics). It is known that there are differences in the digit ratio between ethnic groups (Manning et al. 2002, 2003, 2004) although it is not clear why. Moreover, we urge researchers and journals not just to publish positive findings but also null-findings.

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## A Instruction for Saliva Collection

### Instructions for Saliva Collection

Terminal: \_\_

In this experiment we are collecting saliva from the participants (you). The saliva is analyzed for the hormones it contains. You have received a collection tube. We need it about half full. Please do not eat, drink or chew any chewing gum other than provided by the experimenter during the experiment, as this will affect your saliva.

### How to collect saliva?

1. Chew one piece of Trident original sugarless chewing gum to stimulate saliva.
2. After half a minute, spit the gum out into a tissue.
3. Uncap the collection tube.
4. A short straw is provided for you. Please place it in the tube.
5. Drool saliva through the straw into the tube until it is approximately half full.
6. Remove the straw onto a tissue.
7. Recap the tube.

The experimenters will collect the tubes during the experiment.

The used chewing, straws and tissues should be deposited into the rubbish bin at the end of the experiment.

If you have any questions, please raise your hand and an experimenter will attend to your question.

## B Salivary Hormone Methodology

### B.1 Steroid Hormones

We focus on four steroid hormones: testosterone, estradiol, progesterone, and cortisol (for overviews, see Nelson, 2011). Testosterone,  $C_{19}H_{28}O_2$ , belongs to the androgen group. It is derived via some intermediated steps from cholesterol and secreted in the testis, ovaries, and adrenal gland. Some of it is aromatized into estradiol. Since it is observed in most vertebrates, it must have a long evolutionary history (Mechoulam et al., 1984). Testosterone has anabolic effects such as stimulating the bone density and muscle mass as well as androgenic effects such as the maturation of sex organs and secondary sex characteristics especially in males. It is

necessary for sperm development. In humans, various behavioral correlations with testosterone have been reported mostly pertaining to aggression (e.g. Archer, 1991) and dominance (e.g. Mazur and Booth, 1998, Mehta and Josephs, 2006).

Estradiol,  $C_{18}H_{24}O_2$ , sometimes also named as E2 or  $17\beta$ -estradiol, is a member of the estrogen group. It is also derived via some intermediated steps from cholesterol and secreted in the testis, ovaries, and the adrenal cortex. It changes over the menstrual cycle (see Figure 8). However, in blood plasma, estradiol is bound to globulin and albumin, and only a small fraction is free and biologically active. This fraction is constant over the menstrual cycle (Wu et al., 1976). Estradiol enters cells relatively freely. Its anabolic effects include effects on the bone structure and its androgenic effects are on the maturation of female sex organs and secondary sex characteristics.

Progesterone,  $C_{20}H_{30}O_2$ , sometimes denoted by P4, belongs to the progesten group. It is derived from cholesterol, secreted in the ovaries, especially the corpus luteum, the adrenal glands, and during pregnancy in the placenta. It is also contained in milk. Progesterone is stored in fat tissue. It can be metabolized (via some intermediate steps) into cortisol, testosterone, and estradiol. Progesterone changes over the menstrual cycle (see Figure 8) rising after ovulation and declining before menstruation. As its name suggests, it plays a prominent role during pregnancy (“pro-gestation”). Progesterone is a neurosteroid that can be synthesized within the central nervous system. There is a surprisingly small literature on behavioral effects in humans. Brown et al. (2009) observes an increase of progesterone in females after tasks involving “social closeness”.

Cortisol,  $C_{21}H_{30}O_5$ , is a steroid hormone belonging to glucocorticoid group. It is secreted in adrenal glands and controlled by hypothalamus. It is considered to be the “stress hormone” since it is released in response to stress. It increases blood sugar, suppresses the immune system, and is aiding fat, protein, and carbohydrate metabolism. As the other steroid hormones, it is derived from cholesterol via some intermediated steps. Massage (Field et al. 2005), intimacy (Ditzen et al., 2007, 2008), and sexual arousal (Hamilton and Meston, 2011) reduce cortisol levels. Caffeine (Lovallo et al., 2006) and sleep deprivation (Leprout et al, 1997) can increase cortisol levels. Cortisol follows a typical circadian cycle. On average it peaks at 8:00 am and is lowest at 4:00 am. In terms of behavioral effects, cortisol may interact with testosterone. For instance, Mehta and Josephs (2010) report that testosterone is positively correlated with dominance in low cortisol males while negatively correlated in high cortisol males.

## B.2 Further Details on Saliva Collection and Storage

All sessions were run between February 8 and March 16, 2010, at the same time of the day in the afternoon. This is important as some hormones such as cortisol follow a circadian cycle (Van Cauter and Turek, 1995). The starting time of each session, 16:00, was scheduled such as to have sufficient time passed after lunch and complete the session before dinner time. This is because salivary testosterone or cortisol may respond to meals 30 to 60 minutes before saliva collection (e.g. Al-Dujaili and Bryant, 2005). For testosterone, late-afternoon collections represented samples with physiologically relevant “low” hormone concentrations (Granger et al., 2004).

We must mention that the switch to Daylight Saving Time occurred on March 14, 2010. Although, we were not able to find studies analyzing the effect of Daylight Saving Time on

cortisol or other steroid hormones, it is known from Valdez et al. (2003) and Kantermann et al. (2007) that the switch to Daylight Saving Time may affect the circadian cycle. Thus, salivary hormones from subjects in sessions on March 15 and 16 may be affected by Daylight Saving Time. We will analyze this issue below.

Saliva samples were stored immediately after collection at  $-20^{\circ}\text{C}$  till the end of March 2010 and then at  $-80^{\circ}\text{C}$  till May 2010 when they were assayed. Granger et al. (2004) study testosterone concentration in stored saliva samples. They found no associations between testosterone levels and storage duration for samples stored at  $-80^{\circ}\text{C}$  over a period of 36 months. The same applies for samples collected in the late afternoon and stored at  $-20^{\circ}\text{C}$  over a period of 24 months.

### B.3 Assays

Assays were conducted by the Endocrine Core Laboratory of the California National Primate Research Center at the University of California, Davis. Prior to assay of cortisol, progesterone, estradiol and testosterone, saliva samples were centrifuged at 3000 rpm for 20 min to separate the aqueous component from mucins and other suspended particles.

Salivary concentrations of testosterone were estimated in duplicate using the salivary testosterone enzyme immunoassay kit (Salimetrics LLC, State College, PA). Assay procedures were run in accordance to manufacturer's protocol salivary testosterone enzyme immunoassay kit insert revision 2-2010. The salivary testosterone assay has a least detectable dose of 1.0 pg/mL, and intra- and inter-assay coefficients of variation were 4.44 and 7.96, respectively.

Salivary concentrations of estradiol were estimated in duplicate using the high sensitivity salivary  $17\beta$ -estradiol enzyme immunoassay kit (Salimetrics LLC, State College, PA). Assay procedures were run in accordance to manufacturer's protocol HS Salivary  $17\beta$ -Estradiol EIA Kit Insert, revision date 2-22-10. The salivary estradiol assay has a least detectable dose of 0.1 pg/mL, and intra- and inter-assay coefficients of variation were 3.43 and 6.01, respectively.

Salivary concentrations of progesterone were estimated in duplicate using commercial radioimmunoassay kits (Siemens Healthcare Diagnostics, Inc., Los Angeles, CA). Assay procedures were modified to accommodate overall lower levels of progesterone in human saliva relative to plasma as follows: (1) standards were diluted to concentrations ranging from 0.05–4.0 ng/mL, and (2) sample volume was increased to 200  $\mu\text{l}$ . The salivary progesterone assay has a least detectable dose of 0.00914 ng/ml, and intra- and inter-assay coefficients of variation were 4.15 and 5.84, respectively.

Salivary concentrations of cortisol were estimated in duplicate using commercial radioimmunoassay kits (Siemens Healthcare Diagnostics, Inc., Los Angeles, CA). Assay procedures were modified to accommodate overall lower levels of cortisol in human saliva relative to plasma as follows: (1) standards were diluted to concentrations ranging from 2.76 to 345 nmol/L, (2) sample volume was increased to 200  $\mu\text{l}$ , and (3) incubation times were extended to 3 h. Serial dilution of samples indicates that the modified assay displays a linearity of 0.98 and a least detectable dose of 1.3854 nmol/L. Intra- and inter-assay coefficients of variation are 5.44 and 6.12, respectively.

## B.4 Factors Affecting Salivary Hormones

As mentioned above, the quality of saliva samples may be compromised by food intake prior collection. To control for such effects, we asked subjects in the questionnaire to report whether or not they had lunch today, when they had lunch today, about the time they ate last, what they ate last, about the time they drunk last, and what they drunk last. From this we construct variables “When lunch today” that is zero if lunch was skipped and monotonically increases with the lunch time of the day. Similarly, we construct variables “Time last eaten” and “Time last drunken” that monotonically increase with the time since last eaten (resp. drunk).

Granger et al. (2004) and Kivlighan et al. (2004) show that salivary testosterone may be increased by blood contamination through microinjuries in the mouth or teeth brushing. Similarly, Kivlighan, Granger, and Schwartz (2005) observed decreased levels of salivary estradiol and increased levels of salivary progesterone due to microinjuries in the mouth or teeth brushing. Kivlighan et al. (2004) found that cortisol is irresponsive to microinjuries in the mouth or teeth brushing. To control for potential blood contamination, we asked subjects in the questionnaire to report on their daily dental care, the last time they brushed their teeth and whether they know of any injuries in their mouth. From this information we construct a dummy variable for “Mouth injuries”, and variables “Freq. teethbrush.” and “Time last teethbrush.”, respectively.

Smoking may impact the endocrine system (Kapoor and Jones, 2005) but the evidence is mixed. Zumoff et al. (1990) show an association of smoking on serum levels of progesterone and estradiol but Thomas et al. (1993) were unable to find significant effects of smoking on salivary progesterone, plasma testosterone, and urinary estradiol. The use of tobacco can affect salivary testosterone levels (Attia et al., 1989). We don’t know whether smoking could change the endocrine system or just measurable levels of salivary hormones. Anyway we asked in the questionnaire to self-report the frequency of smoking and created a variable “Smoking” that is monotonically increasing in the frequency of smoking.

As mentioned above the switch to Daylight Saving Time on March 14, 2010, may affect our data collected on March 15 and 16. Although, we were not able to find studies analyzing the effect of Daylight Saving Time on cortisol or other steroid hormones, it is know from Valdez et al. (2003) and Kantermann et al. (2007) that the switch to Daylight Saving Time may affect the circadian cycle. We created a dummy variable “Daylight Sav. Time” that is one for sessions March 15 and 16 and zero otherwise.

In the questionnaire (see Appendix D) we collected further information on factors that may affect salivary hormones. Ellison and Lager (1986) report that moderate recreational running may be associated with lower salivary progesterone levels in females. Thus, we collect information on physical exercise scheduled. Brown et al. (2009) indicate that “social closeness” may effect progesterone. We asked for dating activities, whether students live alone, with family etc. Hooper et al. (2009) report associations between soy consumption and endocrinological factors. While they did not find an effect of soy consumption on estradiol, they found significantly reduced FSH and LH and increased menstrual cycle length. Our sample contains a large fraction of Asians and soybean protein is relatively common in ethnic asian food. Besides race, we also for dietary preferences. Obesity has been linked to abnormal menstrual cycles and deficient progesterone secretion (Jain et al. 2007). Therefore we collect information on height and weight. While all those factors may affect hormones, they may not necessarily affect the quality of the assays. Thus, we do not include them in the analysis of quality. Yet, the analysis is available

from the author on request and can be produced from the Stata datasets and the do-file available from <http://www.econ.ucdavis.edu/faculty/schipper/>

In Table 21, we present results from OLS regressions of salivary hormone levels normalized by their standard deviation on above mentioned variables and session dummies by gender. “T”, “E”, “P”, and “C” refer to testosterone, estradiol, progesterone, and cortisol, respectively. “F” and “M” refer to female and male, respectively. We use robust standard errors to adjust for potential heteroscedasticity and non-normality. We observe that whenever a variable is significant, then the coefficient is close to zero with four exceptions. Testosterone and cortisol of males (specifications TM and CM, respectively) where “When lunch today” on average decreases testosterone by 0.07 of its standard deviation and cortisol by 0.13 of its standard deviation, respectively. Moreover, for estradiol in males we find that the frequency of smoking is positively correlated with salivary estradiol (specification EM). Finally, the frequency of brushing teeth is positively correlated with cortisol in males only (specification CM). This is somewhat surprising given that Kivlighan et al. (2004) found that cortisol is irresponsive to microinjuries in the mouth or teeth brushing. Some of the variables we used in robustness checks of our results.

Table 21: Quality of Salivary Hormones

|                               | (TF)                  | (TM)                  | (EF)                | (EM)                  | (PF)                | (PM)                   | (CF)                  | (CM)                  |
|-------------------------------|-----------------------|-----------------------|---------------------|-----------------------|---------------------|------------------------|-----------------------|-----------------------|
| When lunch today              | -0.0099<br>(0.0211)   | -0.0703**<br>(0.0295) | -0.0588<br>(0.0727) | 0.0150<br>(0.0370)    | -0.0901<br>(0.0660) | -0.0220<br>(0.0210)    | -0.0529<br>(0.0421)   | -0.1341**<br>(0.0567) |
| Time last eaten               | -0.0005<br>(0.0005)   | 0.0017*<br>(0.0009)   | -0.0015<br>(0.0017) | -0.0002<br>(0.0009)   | -0.0022<br>(0.0016) | -0.0019***<br>(0.0007) | -0.0019**<br>(0.0008) | -0.0029*<br>(0.0015)  |
| Time last drunken             | -0.0024**<br>(0.0012) | -0.0023<br>(0.0017)   | -0.0046<br>(0.0029) | 0.0013<br>(0.0017)    | -0.0044<br>(0.0040) | -0.0003<br>(0.0011)    | -0.0035<br>(0.0022)   | 0.0007<br>(0.0020)    |
| Mouth injuries                | -0.0571<br>(0.0963)   | 0.2321<br>(0.2340)    | -0.2568<br>(0.3165) | 0.0989<br>(0.2223)    | 0.1947<br>(0.4825)  | -0.0797<br>(0.1793)    | 0.1736<br>(0.2256)    | -0.0773<br>(0.2193)   |
| Freq. teethbrush.             | 0.1487<br>(0.1082)    | 0.0585<br>(0.1168)    | 0.1030<br>(0.2610)  | 0.1236<br>(0.1182)    | -0.5213<br>(0.3491) | 0.1655*<br>(0.0974)    | -0.0380<br>(0.1452)   | 0.3596**<br>(0.1580)  |
| Time last teethbrush.         | -0.0026<br>(0.0044)   | -0.0047*<br>(0.0024)  | 0.0020<br>(0.0054)  | -0.0088**<br>(0.0040) | -0.0027<br>(0.0040) | -0.0047***<br>(0.0017) | -0.0116<br>(0.0070)   | 0.0003<br>(0.0029)    |
| Smoking                       | 0.0495<br>(0.1096)    | 0.1046<br>(0.1305)    | 0.4001<br>(0.2703)  | 0.4167**<br>(0.1969)  | 0.1090<br>(0.2889)  | 0.0999<br>(0.1124)     | -0.0564<br>(0.2054)   | 0.1444<br>(0.2353)    |
| Daylight Sav. Time            | 0.2276<br>(0.2136)    | -0.1032<br>(0.2632)   | 0.3933<br>(0.6583)  | 0.1314<br>(0.3033)    | 0.3975<br>(0.8050)  | 0.0109<br>(0.1330)     | 1.5397*<br>(0.8122)   | -0.1674<br>(0.2983)   |
| <i>Number of Observations</i> | 93                    | 115                   | 93                  | 115                   | 93                  | 114                    | 93                    | 114                   |
| <i>R<sup>2</sup></i>          | 0.0980                | 0.1630                | 0.0763              | 0.1814                | 0.0738              | 0.2009                 | 0.2684                | 0.1605                |

Robust standard errors in parentheses; Significance levels: \*10%; \*\* 5%; \*\*\* 1%.

# C Holt-Laury Lottery Task

## Instructions for the Lottery Experiment

Terminal: \_\_

Along with these instructions, you have received two decision sheets. Each of them shows ten decisions listed on the left. Each decision is a paired choice: either "Option A" or "Option B." On each sheet, you will make ten choices and record these in the final column, but only one of them from each sheet will be used in the end to determine your earnings. Before you start making your ten choices, please let me explain how these choices will affect your earnings for this part of the experiment.

There is a ten-sided die that will be used to determine payoffs in front of your eyes; the faces are numbered from 1 to 10 (the "0" face of the die will serve as 10). After you have made all of your choices, we will throw this die twice for each decision sheet, once to select one of the ten decisions of the sheet to be used, and a second time to determine what your payoff is for the option you chose, A or B, for the particular decision selected. Even though you will make ten decisions on each sheet, only one of these from each sheet will end up affecting your earnings, but you will not know in advance which decisions will be used. Obviously, each decision has an equal chance of being used in the end.

Now, please look at Decision 1 at the top of the first sheet. Option A yields a sure gain of \$3.20 (320 cents), and option B yields a sure gain of \$0.20 (20 cents). Next look at Decision 2 in the second row. Option A yields \$4.00 if the throw of the ten sided die is 1, and it yields \$3.20 if the throw is 2-10. Option B yields \$7.70 if the throw of the die is 1, and it yields \$0.20 if the throw is 2-10. The other decisions on the sheet are similar, except that as you move down the table, the chances of the better payoff for each option increase.

The second decision sheet is identical to the first one except for one difference: all payoffs are negative. For instance look at Decision 1 at the top of the second sheet. Option A yields a sure loss of \$3.20 (minus 320 cents), and option B yields a sure loss of \$0.20 (minus 20 cents). Payoffs for this choice are negative and will be subtracted from your previous earnings.

To summarize, on each decision sheet you will make ten choices: for each decision row you will have to choose between Option A and Option B. You may choose A for some decision rows and B for other rows, and you may change your decisions and make them in any order. When you are finished, we will come to your desk and collect both decision sheets. Then the market experiment will be run. After the market experiment we will throw the ten-sided die for each decision sheet to select which of the ten Decisions will be used. Then we will throw the die again for each decision sheet to determine your payoff for the Option you chose for that Decision. Payoffs for your choices and will be added/subtracted to/from your previous earnings from the market experiment, and you will be paid the sum of all earnings in cash when we finish.

So now please look at the empty boxes on the right side of the record sheet. You will have to write a decision, A or B in each of these boxes, and then the die throw will determine which one is going to count. We will look at the decision that you made for the choice that counts, and circle it, before throwing the die again to determine your earnings for this part. Then you will write your earnings in the blank at the bottom of the page. Please note that these gains/losses will be added/subtracted to/from your previous earnings up to now.

Are there any questions? Now you may begin making your choices. Please do not talk with anyone while we are doing this; raise your hand if you have a question.



Terminal: \_\_\_\_\_

Session No.: \_\_\_\_\_

**Decision Sheet (Gains)**

|             | <b>Option A</b>   | <b>Option B</b>   | <b>Your Choice A or B</b> |
|-------------|---|---|---------------------------|
| Decision 1  | \$3.20 if throw of die is 1 to 10                                     | \$0.20 if throw of die is 1 to 10                                     |                           |
| Decision 2  | \$4.00 if throw of die is 1<br>\$3.20 if throw of die is 2 to 10      | \$7.70 if throw of die is 1<br>\$0.20 if throw of die is 2 to 10      |                           |
| Decision 3  | \$4.00 if throw of die is 1 or 2<br>\$3.20 if throw of die is 3 to 10 | \$7.70 if throw of die is 1 or 2<br>\$0.20 if throw of die is 3 to 10 |                           |
| Decision 4  | \$4.00 if throw of die is 1 to 3<br>\$3.20 if throw of die is 4 to 10 | \$7.70 if throw of die is 1 to 3<br>\$0.20 if throw of die is 4 to 10 |                           |
| Decision 5  | \$4.00 if throw of die is 1 to 4<br>\$3.20 if throw of die is 5 to 10 | \$7.70 if throw of die is 1 to 4<br>\$0.20 if throw of die is 5 to 10 |                           |
| Decision 6  | \$4.00 if throw of die is 1 to 5<br>\$3.20 if throw of die is 6 to 10 | \$7.70 if throw of die is 1 to 5<br>\$0.20 if throw of die is 6 to 10 |                           |
| Decision 7  | \$4.00 if throw of die is 1 to 6<br>\$3.20 if throw of die is 7 to 10 | \$7.70 if throw of die is 1 to 6<br>\$0.20 if throw of die is 7 to 10 |                           |
| Decision 8  | \$4.00 if throw of die is 1 to 7<br>\$3.20 if throw of die is 8 to 10 | \$7.70 if throw of die is 1 to 7<br>\$0.20 if throw of die is 8 to 10 |                           |
| Decision 9  | \$4.00 if throw of die is 1 to 8<br>\$3.20 if throw of die is 9 or 10 | \$7.70 if throw of die is 1 to 8<br>\$0.20 if throw of die is 9 or 10 |                           |
| Decision 10 | \$4.00 if throw of die is 1 to 9<br>\$3.20 if throw of die is 10      | \$7.70 if throw of die is 1 to 9<br>\$0.20 if throw of die is 10      |                           |

Decision used: \_\_\_\_\_ Die throw: \_\_\_\_\_

Your earnings on this sheet: \_\_\_\_\_

Terminal: \_\_\_\_

Session No.: \_\_\_\_\_

**Decision Sheet (Losses)**

|             | <b>Option A</b>   | <b>Option B</b>   | <b>Your Choice A or B</b> |
|-------------|---|---|---------------------------|
| Decision 1  | -\$3.20 if throw of die is 1 to 10                                      | -\$0.20 if throw of die is 1 to 10                                      |                           |
| Decision 2  | -\$4.00 if throw of die is 1<br>-\$3.20 if throw of die is 2 to 10      | -\$7.70 if throw of die is 1<br>-\$0.20 if throw of die is 2 to 10      |                           |
| Decision 3  | -\$4.00 if throw of die is 1 or 2<br>-\$3.20 if throw of die is 3 to 10 | -\$7.70 if throw of die is 1 or 2<br>-\$0.20 if throw of die is 3 to 10 |                           |
| Decision 4  | -\$4.00 if throw of die is 1 to 3<br>-\$3.20 if throw of die is 4 to 10 | -\$7.70 if throw of die is 1 to 3<br>-\$0.20 if throw of die is 4 to 10 |                           |
| Decision 5  | -\$4.00 if throw of die is 1 to 4<br>-\$3.20 if throw of die is 5 to 10 | -\$7.70 if throw of die is 1 to 4<br>-\$0.20 if throw of die is 5 to 10 |                           |
| Decision 6  | -\$4.00 if throw of die is 1 to 5<br>-\$3.20 if throw of die is 6 to 10 | -\$7.70 if throw of die is 1 to 5<br>-\$0.20 if throw of die is 6 to 10 |                           |
| Decision 7  | -\$4.00 if throw of die is 1 to 6<br>-\$3.20 if throw of die is 7 to 10 | -\$7.70 if throw of die is 1 to 6<br>-\$0.20 if throw of die is 7 to 10 |                           |
| Decision 8  | -\$4.00 if throw of die is 1 to 7<br>-\$3.20 if throw of die is 8 to 10 | -\$7.70 if throw of die is 1 to 7<br>-\$0.20 if throw of die is 8 to 10 |                           |
| Decision 9  | -\$4.00 if throw of die is 1 to 8<br>-\$3.20 if throw of die is 9 or 10 | -\$7.70 if throw of die is 1 to 8<br>-\$0.20 if throw of die is 9 or 10 |                           |
| Decision 10 | -\$4.00 if throw of die is 1 to 9<br>-\$3.20 if throw of die is 10      | -\$7.70 if throw of die is 1 to 9<br>-\$0.20 if throw of die is 10      |                           |

Decision used: \_\_\_\_\_ Die throw: \_\_\_\_\_

Your earnings on this sheet: \_\_\_\_\_

# D Questionnaire

## **SURVEY (collected on the subject's computer terminal)**

We are interested in whether there is a correlation between participants' bidding behavior and some socio-psychological and biological factors. It is an extremely important part of our research. This information will be strictly confidential.

1. What is your (biological) sex?

- Male
- Female

2. What is your sexual orientation?

- Heterosexual
- Homosexual
- Bisexual
- Transsexual

3. Are you currently in a relationship?

- No
- Married
- Boyfriend/girlfriend

4. How many people did you date within the last year? (drop down menu)

- None
- 1 person
- 2 persons
- 3 persons
- 4 persons
- 5 persons
- 6 persons
- 7 persons
- 8 persons
- 9 persons
- 10 persons
- More than 10 persons

5. Do you have children? (drop down menu)

- No
- 1 child
- 2 children
- 3 children
- 4 children
- More than 4 children

6. What is your ethnic origin? (You may choose several.)
- White
  - Asian/Asian American
  - African American
  - Hispanic/Latino
  - Native American
  - Other
7. What is your age (in years)? \_\_\_\_\_
8. What is your weight (in pounds)? \_\_\_\_\_
9. What is your height (in inches)? \_\_\_\_\_ (*Remark: We helped them to calculate if known only in feet or cm*)
10. How many siblings do you have?  
I have \_\_\_ younger siblings.  
I have \_\_\_ older siblings.
11. How often do you exercise in an average week?
- Never
  - At least once a week
  - At least twice a week
  - At least three times a week
  - Four or more times a week
12. Have you ever broken a finger on your right hand?
- No
  - Yes
13. If yes, was it the pointer or ring finger?
- Yes
  - No
14. Would you describe your personality as (please choose one)
- optimistic
  - pessimistic
  - neither
15. Which of the following emotions did you experience during the experiment?  
(You may choose any number of them.)
- anger
  - anxiety

- confusion
- contentment
- fatigue
- happiness
- irritation
- mood swings
- withdrawal

16. Do you live
- alone
  - with your parents
  - with your partner/boyfriend/girlfriend/spouse
  - with a roommate?

For female participants only:

17. Are you pregnant?
- No
  - Yes
  - May be
18. How many days ago was the first day of your **last** menstrual period? \_\_\_\_\_
19. What is your best guess on how many days until your **next** menstrual cycle? \_\_\_\_\_
20. On average, how many days are there between your menstrual periods?
- less than 25 days
  - 25 days
  - 26 days
  - 27 days
  - 28 days
  - 29 days
  - 30 days
  - 31 days
  - 32 days
  - 33 days
  - 34 days
  - 35 days
  - more than 35 days
21. Do you often experience changes in the length of your menstrual cycle?
- No, it is quite regular and almost always takes the same number of days.
  - The length is irregular.

22. Do you keep a menstrual cycle calendar?
- Yes
  - No
23. Do you usually experience any symptoms of PMS? (please choose one)
- None
  - Mild**
  - Severe
24. Are you currently experiencing any symptoms of PMS (please choose one)
- None
  - Mild
  - Severe
25. Do you currently use a hormone-based contraceptive (birth control pill, IUD, contraceptive patch [OrthoEvra], vaginal ring [Nuvaring], Norplant, IUS, injection [DepoProvera, Lunelle], etc.)?
- Yes
  - No
26. If yes, what type? \_\_\_\_\_

For all participants:

27. Do you smoke?
- Daily
  - Occasionally
  - Never
28. Do you regularly take dietary supplements that help you perform better in sports?
- No
  - Yes
29. If yes, what type? \_\_\_\_\_
30. Are you vegetarian or vegan?
- No
  - Yes
31. Do you regularly eat soybean-based food like tofu, soymilk etc.?
- Not at all
  - Not very often
  - Yes, daily

- Yes, several times a week
32. When did you have lunch today?
- I skipped lunch
  - 11.00 am
  - 12.00 pm
  - 1.00 pm
  - 2.00 pm
  - 3.00 pm
33. Before arriving at the experiment, how long has it been since you last ate?
- 30 min
  - 1 hour
  - 2 hours
  - 3 hours
  - 4 hours
  - More than 4 hours ago
34. What did you eat last? \_\_\_\_\_
35. Did you drink coffee/tee/other drinks in the past two hours before arriving at the experiment?
- Yes, within 30 min before the experiment
  - Yes, within 1 hour before the experiment
  - Yes, within 1.5 hours before the experiment
  - Yes, within 2 hours before the experiment
36. What did you drink last? \_\_\_\_\_
37. Do you currently have any small injuries in your mouth or gums (cuts, sores, bleeding)?
- Yes
  - No
38. How many times a day do you brush your teeth?
- Never
  - Once a day
  - Twice a day
  - Three times a day
  - More than three times a day
39. When was the last time you brushed your teeth?
- 30 minutes ago
  - 1 hours ago

- 2 hours ago
- 3 hours ago
- More than 3 hours ago

40. What was your SAT score? \_\_\_\_\_

41. What is your major field of study?

- Economics
- Mathematics
- Other Social Science
- English
- Other Arts/Humanities
- Chemistry/Biology/Physics
- Other Natural Science
- Engineering

42. What is your current GPA? \_\_\_\_\_

43. If you are student, how many quarters have you completed? \_\_\_\_\_