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Sex Hormones and Competitive Bidding

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University of California, Davis

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Paper # 12-8

We correlate competitive bidding and profits in symmetric independent private value first-price auctions with salivary testosterone, estradiol, progesterone, and cortisol in more than 200 subjects. Females bid significantly higher and earn significantly lower profits than males. Moreover, females on hormonal contraceptives bid significantly higher and earn significantly lower profits than males. Bids are significantly positively correlated and profits are significantly negatively correlated with salivary progesterone when controlling for gender, the use of hormonal contraceptives, and demographics. This also applies to the female but not to the male subsamples separately. It especially applies to naturally cycling females not using hormonal contraceptives and to females in the luteal phase of their natural menstrual cycle when progesterone usually peaks. Surprisingly, we have null findings for testosterone as well as estradiol and cortisol. Controlling for risk aversion does not diminish our positive finding for progesterone. Yet, we show that our finding may be due to subjects with imprudent bidding behavior (i.e., weakly dominated bids).

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SEX HORMONES AND COMPETITIVE BIDDING*

Burkhard C. Schipper[†]

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Abstract

We correlate competitive bidding and profits in symmetric independent private value first-price auctions with salivary testosterone, estradiol, progesterone, and cortisol in more than 200 subjects. Females bid significantly higher and earn significantly lower profits than males. Moreover, females on hormonal contraceptives bid significantly higher and earn significantly lower profits than males. Bids are significantly positively correlated and profits are significantly negatively correlated with salivary progesterone when controlling for gender, the use of hormonal contraceptives, and demographics. This also applies to the female but not to the male subsamples separately. It especially applies to naturally cycling females not using hormonal contraceptives and to females in the luteal phase of their natural menstrual cycle when progesterone usually peaks. Surprisingly, we have null findings for testosterone as well as estradiol and cortisol. Controlling for risk aversion does not diminish our positive finding for progesterone. Yet, we show that our finding may be due to subjects with imprudent bidding behavior (i.e., weakly dominated bids).

Keywords: Hormones, Testosterone, Estradiol, Progesterone, Cortisol, Steroids, Auctions, Gender, Competition, Aggression, Dominance, Risk-taking, Endocrinological economics.

JEL-Classifications: C72, C91, C92, D44, D81, D87.

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1 Introduction

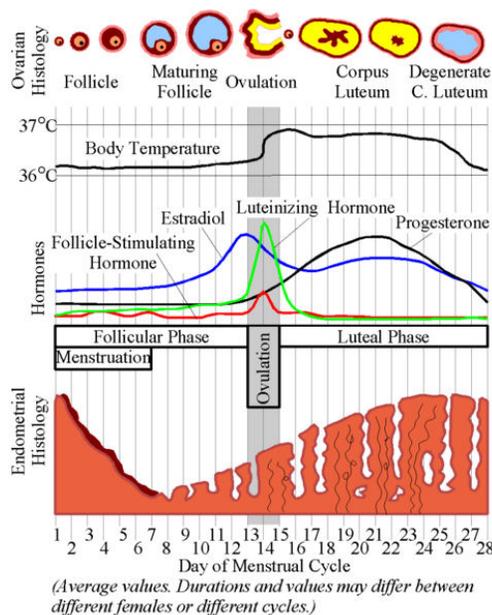
Auction games are one of the most important classes of mechanisms used to allocate optimally objects among agents with unknown valuations. They are widely used in financial markets, business-to-business relationships (like online advertising auctions, FCC spectrum auctions, timber auctions) but also in business-to-consumer relationships (like Ebay, charity auctions, etc.) some involving a huge number of transactions and billions of dollars in revenues. One of the theoretically best-understood auction formats is the first-price auction. In a first-price auction, the highest bidder wins and pays his/her bid.

There is independently replicated experimental evidence that on average women bid higher than men in first-price auctions.¹ Casari, Ham, and Kagel (2007) report significantly different bidding behavior between men and women in sealed bid first-price common value auctions. Initially, women bid significantly higher than men and thus are more prone to the winner's curse. However, women also learn bidding much faster than men, thus eventually their earnings may slightly surpass those of men. Ham and Kagel (2006) report that females bid significantly higher than men in two-stage first-price private value auctions. Chen, Katuščák, and Ozdenoren (2009) show that women bid significantly higher and earn significantly less than men in first-price auctions with independent symmetric private values, while no such differences are observed in second-price auctions. The authors go a step further by studying how bidding and profits differ across the 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 1). Thus menstrual cycle information provide for relative easy to observe within-female measures of some hormones. Chen, Katuščák, and Ozdenoren (2009) report that women bid higher than men in *all* phases of their menstrual cycle in the first-price auction but not in the second-price auction. Using the same first-price auctions as Chen, Katuščák, and Ozdenoren (2009), Pearson and Schipper (2011) replicate their finding with regard to gender differences. Yet, with regard to menstrual cycle information, Pearson and Schipper (2011) report that naturally cycling women bid significantly higher than men and earn significantly lower profits than men except during the midcycle when fecundity is highest. They suggest an evolutionary hypothesis according to which women are predisposed by hormones to generally behave more riskily during their fecund phase of their menstrual cycle in order to increase the probability of conception, the quality of offspring, and genetic variety. They also find that women on hormonal contraceptives bid significantly higher and earn substantially lower profits than men. All hormonal contraceptives contain progestin, a synthetic version of progesterone, and sometimes also

¹More generally, gender differences 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) continue to puzzle economists and policy makers. 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).

estradiol. The correlation between the use of hormonal contraceptives and bidding or profits may be due to the hormones contained in the contraceptives but it may also be just a selection effect. Nevertheless, both the correlation of bidding and profits with menstrual cycle phases and the correlation between the use of hormonal contraceptives and bidding or profits suggests that sex hormones may effect competitive bidding and profits in first-price auctions. Finally, we like to mention that using a supersample of our current study, Pearson and Schipper (2012) show a null result for the correlation between the digit ratio (2D:4D), a measure of prenatal exposure to testosterone and estrogen, and competitive bidding or profits in first-price auctions. To summarize the literature, we have clear evidence of gender differences in first-price auctions. But there is only indirect evidence that the gender differences may be due to differences in sex hormones.

Figure 1: Menstrual Cycle



<http://en.wikipedia.org/wiki/Image:MenstrualCycle2.png>

In order to get a clearer understanding of the role of sex hormones for competitive bidding in first-price auctions, we conduct an experiment in which we collect salivary steroid hormones such as testosterone, estradiol, progesterone, and cortisol. As mentioned previously, estradiol and progesterone play a prominent role in the menstrual cycle. For males, testosterone has been shown to be significantly negatively correlated with risk aversion in an investment task (Apicella et al. 2008) and a lottery choice task for gains (Schipper, 2012) although Sapienza et al. (2009) find only an insignificant relationship when controlling for gender. Schipper (2012) finds a null result for females. Using a placebo-controlled experiment and a sample of 200 postmenopausal women, Zethraeus et al. (2009) did not find a correlation between randomly administered testosterone or

estrogen and risk-taking. Risk aversion increases equilibrium bids in first-price auctions. To see this, note that a higher bid translates into a higher probability of winning the auction, but it also leads to a lower profit conditional on winning the auction. Because of the association between testosterone and risk aversion found in the literature on one hand and the effect of risk aversion in first-price auctions on the other hand, we find it highly relevant to include testosterone into our analysis. Finally, we also collect salivary cortisol. Cortisol is a stress hormone. We believe that there is an intuitive relationship between stress, risk-taking, and competition.

We observe that females bid significantly higher and earn significantly lower profits than males. Moreover, females on hormonal contraceptives bid significantly higher and earn significantly lower profits than males. Bids are significantly positively correlated and profits are significantly negatively correlated with salivary progesterone when controlling for gender, the use of hormonal contraceptives, and demographics. This observation also applies to our female subsample separately but not to our male subsample. No significant correlations are observed between bidding or profits and salivary testosterone, estradiol, and cortisol. This is surprising given the positive association of testosterone and risk-taking found in the previous literature (Apicella et al., 2008, Schipper, 2012; but for insignificant findings see Sapienza et al. 2009 and Zethraeus et al., 2009, discussed above), the prominent role of estradiol in the menstrual cycle especially before ovulation (see Figure 1), and - with regard to cortisol - the intuitive association between stress and competitive bidding. Our observations with respect to progesterone become insignificant when conservative Bonferroni adjustments are made for multiple testing of four hormones. We discuss the issue of multiple testing and the trade off between false positives and false negatives in Section 7.

How could progesterone effect bidding and profits in first-price auctions? One hypothesis is that it is correlated with risk preferences. To control for risk preferences in our experiment, we measure risk aversion 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 binary lotteries. The subject has to make a choice between the lotteries for each pair of lotteries in the list (see Section 4). 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) extended it also to lotteries involving monetary losses. The associations between risk aversion for gains and losses, gender, the use of hormonal contraceptives, menstrual cycle information, the digit ratio (a measure of prenatal hormone exposure) and hormonal contraceptives are analyzed in detail in a companion paper, Schipper (2012). There we find that females on hormonal contraceptives make more “consistent” choices although this may be due to a selection effect. Risk aversion for gains is significantly negatively correlated with testosterone and significantly positively correlated with cortisol, a stress hormone. In males, testosterone continues to be significantly negatively correlated with risk aversion for gains, even after Bonferroni correction for multiple testing. No other significant correlations between risk aversion and salivary hormones are observed. When we control for risk preferences in our auction experiment, we still observe a positive finding with respect to progesterone. We

conclude that progesterone may not effect bidding and profits through risk aversion.

Schipper (2012) also shows in the lottery choice task that in females testosterone and progesterone are significantly positively correlated with reflection, i.e., risk aversion for gains and risk seeking for losses. Testosterone is negatively correlated with “consistency” in females, while estradiol is negatively correlated with “consistency” in males. This suggests to investigate “inconsistent” behavior in auctions. One way to classify “inconsistent” behavior in auction is to scrutinize the use of weakly dominated bids, i.e., bids above the valuation of the object. Such bids are imprudent since they may lead to losses without any potential gain. We show that our positive findings with regard to progesterone may be due to subjects with imprudent bidding behavior.

Our paper is related to an increasing literature on endocrinological economics. Most closely related to us is some recent work by Shachat and Wei (2012). They collected salivary testosterone, estradiol, and progesterone in an experiment with first-price auctions and reverse first-price auctions. They reported that a group of women that includes women with higher progesterone have significantly lower profits in the first-price auction than males. Their analysis focuses on the heterogeneity of bidding heuristics. With respect to endocrinological correlates and competition, Wozniak, Harbaugh, and Mayr (2011) 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 (2012) comes to a different conclusions. He observes that women later in their menstrual cycle are relatively more reluctant to choose the winner-take-all compensation.

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. These traders were trading in competitive financial markets with trades ranging from £100,000 to £500,000,000 including trades in risky financial products like interest rate futures. Coates and Herbert (2008) also show that a trader’s salivary cortisol level rises with both the variance of his trading results and the volatility of the market.

Our study relates more generally to the small but growing literature that seeks to correlated 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.

There is also a related literature on economic experiments using placebo-controlled administration of hormones. 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.

The paper is organized as follows: Section 2 outlines the experimental design. The results are reported in Section 3. In Section 4, we discuss in what sense our observations may be due to risk aversion. In Section 5, we show that our main observation may be due to imprudent bidding behavior. We also collected saliva samples at the end of the experiments and these ex post salivary hormone measurements are discussed in Section 6. Finally, in Section 7 we offer our conclusions. The Appendix contains the instructions, screen shots, the questionnaire, and a detailed exposition of the salivary hormone methodology. The Stata datasets and the do-file that reproduces the entire analysis reported here and additional analysis are available from <http://www.econ.ucdavis.edu/faculty/schipper/>.

2 Experimental Design

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[®] 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[®] 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.² 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. In this study, we will use behavioral measures of risk aversion derived from this lottery task just as a control for our analysis of behavior in auctions. The correlations between risk attitudes and salivary hormones are investigated in Schipper (2012).

3. *Auction Game*: Each subject received printed instructions for the auction game (see Appendix D). Subjects were given 5 to 7 minutes to read through the instructions, after which instructions were read aloud by the male experimenter. Then subjects were given time to complete the review questions in private (see Appendix D). The experimenter went through the questions and answers aloud, after which the experimenter discussed and answered any additional questions from the subjects. In total, about 20 minutes of each experimental session was spent on the instructions. We were extremely careful to explain and train our subjects in the 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).

Subjects repeatedly played a two-bidder first-price sealed bid auctions with symmetric independent private values drawn from a piecewise linear distribution function constructed

²Laury 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.

as follows: A bidder’s valuation is drawn separately and independently with probability 0.7 from the “low” distribution L and with probability 0.3 from the “high” distribution H . The support of both distributions is $\{1, 2, \dots, 100\}$. The respective densities, l and h , are given by³

$$l(x) = \begin{cases} \frac{3}{200} & \text{if } x \in \{1, 2, \dots, 50\} \\ \frac{1}{200} & \text{if } x \in \{51, 52, \dots, 100\} \end{cases}$$

$$h(x) = \begin{cases} \frac{1}{200} & \text{if } x \in \{1, 2, \dots, 50\} \\ \frac{3}{200} & \text{if } x \in \{51, 52, \dots, 100\} \end{cases}$$

In each round, the highest bidder wins the imaginary object and pays its bid. If both bids are the same, each bidder wins with equal probability. The profit of the winning bidder is his value minus his bid. The losing bidder’s payoff is zero. Thus, as standard practice in the literature on experimental auctions (e.g. Kagel, 1995, Chapter 7) we induce the value of a bidder for the object by essentially buying it back from the bidder at the price that is his value if he obtains it in the auction.

Each session consisted of 8 subjects who were randomly re-matched in each round. Subjects played 2 practice rounds, the payoffs obtained in these rounds did not count for the final payoff, and then 30 “real” rounds.

At the beginning of each round, bidders were privately informed on their computer screen of their valuation. They then independently entered a bid on the computer. The winner of each pair was determined, and each subject was informed of her/his valuation, bid, whose bid was the winning bid, whether (s)he received the object, and her/his total payoff accumulated so far. (See the Appendix E for screenshots.)

4. *Questionnaire:* After the auction task, subjects completed a computerized questionnaire (see Appendix F). 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. The correlation between the menstrual cycle information and bidding and profits is analyzed in detail in a companion paper,

³The main reason for choosing this process of drawing values (as opposed to uniform distribution) is to be able to replicate Chen, Katusčák, and Ozdenoren (2009). A second reason is to keep the option of comparing in a later study to auctions with ambiguity about values, in which subjects would be left ignorant about the probability with which the value is drawn from the low or high value distribution (see Chen, Katusčák, and Ozdenoren, 2007). Finally, the process makes simple mark-down bidding heuristics such as “bid 10 points below your value if possible” less prominent.

Pearson and Schipper (2011), who use a supersample of the current study. The correlation between menstrual cycle information and choice under risk is analyzed in Schipper (2012).

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 previous questionnaire we also ask subjects to report on any previous fractures of the relevant digits. The correlation between the digit ratio and bidding and profits is analyzed in detail in a companion paper, Pearson and Schipper (2012) who use a supersample of the current study. The correlation between the digit ratio and choice under risk is analyzed in Schipper (2012).

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).

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 1: 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 1 presents the demographics of our data as elicited with the questionnaire (see Appendix F).⁴ 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 by Whites (38%).⁵ 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. Six females and eight males reported to be homo- or bisexual. We do not find robust significant correlations between sexual preferences and salivary hormones.

⁴Subjects were allowed to select multiple majors and ethnic backgrounds. Thus, the means do not add up to unity. We should mention that in our sample all math majors happened to be male.

⁵For 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.

For our analysis, we fix four features. First, to control for correlations across time and subjects, we cluster standard errors at the session level. Recall that subjects play 30 rounds. Hence, their decisions in each round may be correlated due to learning. Moreover, subjects are randomly rematched each round within the session of eight subjects. Hence, their interaction may affect each other’s decisions. By clustering at the session level, we control for such correlations (see Cameron et al., 2008, for a study of clustering in small samples). Since we have 208 subjects in sessions of eight subjects, we have 26 clusters and thus 26 independent observations. Clustering standard errors using `cluster` in Stata also takes care on potential heteroscedasticity and non-normality.

Second, in the multivariate regression analysis of the full sample, all results should be interpreted as compared to white males, the omitted category. Because of their small numbers (see Table 1), we classify all hispanic, black, and participants of other ethnic origins under “Others”.

Third, each specification of regressions on bids also includes a cubic polynomial in the value⁶ and a set of period indicators to control for learning.⁷ Each specification on total profits also includes the mean, the standard deviation, and the skewness of the subject’s empirical distribution of values. We do not report these estimates here but they are available on request and can be reproduced using the Stata do-file and data sets available from the author’s website.

Fourth, our analysis of the correlation between salivary hormones and bidding or profits involves *multiple testing* of four hormones. The chance of falsely observing one hormone to be significantly correlated with bidding or profits is much higher when four hormones are analyzed as compared to when from the beginning just one hormone is analyzed. Thus, the use of p -values may lead to errors of inference, in particular to the underestimation of false positives. We will report not just individual p -values but also point out whether or not results are significant when we correct for multiple testing using Bonferroni correction, a conservative method to correct for multiple testing. 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. A discussion of false positives and false negatives, the Bonferroni correction, and its bearing on the interpretation of our results is included in Section 7.

We estimate versions of the following parametric model for bids:

$$b_{i,t} = \beta_0 + \beta_1 v_{i,t} + \beta_2 v_{i,t}^2 + \beta_3 v_{i,t}^3 + \delta_t p_t + \zeta X_i + \rho H_i + \sigma C_i + \varepsilon_{i,t}, \quad (1)$$

where $b_{i,t}$ is the bid of subject i at time period $t = 1, \dots, 30$, β_0 is a constant, $v_{i,t}$ is

⁶We include a cubic polynomial in order not to force bids to be a linear function of values as risk neutrality or constant relative risk aversion would require (see for instance Cox, Smith, and Walker, 1988). However, we should mention that estimated coefficients for the quadratic and cubic terms are zero and our results do not change in any substantial way when omitting the quadratic and cubic terms.

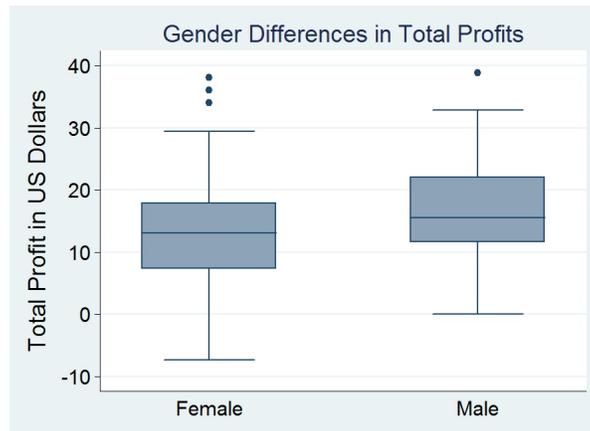
⁷Our results do not change if the time period dummies are replaced by a time period regressor. Period dummies have the advantage of not assuming a necessarily linear effect of time.

the value of subject i at time period t , p_t is a set of period dummies, X_i is a vector of demographic variables including gender, age, race, number of siblings, and majors of study, H_i is a set of salivary hormone variables of subject i , and C_i is a dummy for the use of hormonal contraceptives by subject i . $\varepsilon_{i,t}$ is the unobserved error term of subject i in period t (clustered at the session level). For robustness checks, we will also add in some specification session dummies to control for session effects (e.g., the sex ratio of the session or possibly degraded quality of saliva samples in earlier sessions as compared to later sessions).

Analogous to equation (1), we estimate a parametric model for total dollar profits (summed over all thirty time periods) in which we drop the time period dummies and the cubic polynomial in the value but add the mean, the variance, and the skewness of the subject’s empirical distribution of values as dependent variables. These model will be estimated with ordinary least squares method (OLS).

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 4 and Figure 4 that their absolute levels differ quite a bit. To be better able to interpret the regression results, we normalize hormone levels by dividing them by their standard deviation. For instance, in OLS regressions of profits, the coefficient for any hormone now measures the effect in terms of dollars when that hormone level increases by one standard deviation (keeping everything else constant).

Figure 2: Gender Differences in Total Profits



3.1 Gender Effects

Casari, Ham, and Kagel (2007), Ham and Kagel (2006) as well as Chen, Katuščák, and Ozdenoren (2009) report significant gender differences for common value and private value first-price auctions. Pearson and Schipper (2011) also report significant gender differences

Table 2: Gender Effect on Bids and Profits

	(Bids1)	(Bids2)	(Profits1)	(Profits2)
Age	-0.0394 (0.1356)		0.0186 (0.2138)	
Num. of Siblings	0.3636* (0.1999)		-0.4151 (0.3749)	
Asian	-1.5683** (0.6785)		1.8095* (0.8818)	
Other	-0.4828 (1.3659)		0.1541 (2.1896)	
GPA	-0.3516 (0.6009)	-0.1916 (0.6136)	0.9396 (0.8055)	0.8696 (0.9387)
Mathematics	-0.3139 (1.4160)		3.0936 (2.0345)	
Science & Engineering	0.0276 (0.8160)		1.7377 (1.3223)	
Economics	0.8437 (0.8356)		-0.0526 (1.4565)	
Social Science	0.7244 (0.9134)		-0.4926 (1.4399)	
Humanities	-0.2071 (1.1572)		0.5801 (1.8545)	
Female	2.5171*** (0.6973)	2.1961*** (0.7690)	-4.2932*** (0.9475)	-4.0202*** (0.9663)
<i>Number of Observations</i>	6060	6060	202	202
<i>R</i> ²	0.8577	0.8554	0.2599	0.2260

Robust standard errors (clustered at the session level) in parentheses.

Significance levels: *10%; ** 5%; *** 1%

Not reported: Coefficients of cubic polynomial in values and dummies for bidding rounds (bids), and mean, standard deviation, and skewness of values drawn (profits).

in private value first-price auctions using a supersample of the current study.

For our sample, we observe in Figure 2 that women on average have lower profits than men. The box plot shows the median, the 25% and 75% percentiles, the upper and lower adjacent values as well as outside values. In our regression analysis we find that women bid on average 2.5 points higher ($p = 0.001$, specification “Bids1” in Table 2) than white males when controlling for a basic set of demographics also used in prior studies by Chen, Katuščák, and Ozdenoren (2009) and Pearson and Schipper (2011). Similarly, specification “Profits1” in Table 2 reveals that women earn on average \$4.29 less than white males ($p < 0.001$) when controlling for a basic set of demographic variables. This difference is substantial since it is more than 28% of average total profits made in the auction in our sample.⁸ Note that regressions are not robust to outliers. However, since in Figure 2 we observe for females outliers at the top, our regression coefficient for gender may be even biased downward. Our finding is robust to dropping the demographic

⁸Average earnings in our sample were \$15.02 for the auction game alone.

variables in specifications Bids2 and Profits2 in Table 2. In the last two specifications, we keep GPA as a control in order to show that the effect is not due to differences in GPA. The finding remains robust to dropping GPA (not reported). Casari, Ham, and Kagel (2007) report that the winner’s curse associated with overbidding in common value auctions may be positively correlated with lower academic achievement. Our findings are also robust to the inclusion of additional demographic variables (not reported). Finally, we like to note that our results are robust to the control of session fixed effects (not reported).

Observation 1 (Gender) *Females bid on average significantly higher than men. Females’ profits are on average significantly lower than males’ profits.*

Table 3: Hormonal Contraceptives, Bids, and Profits

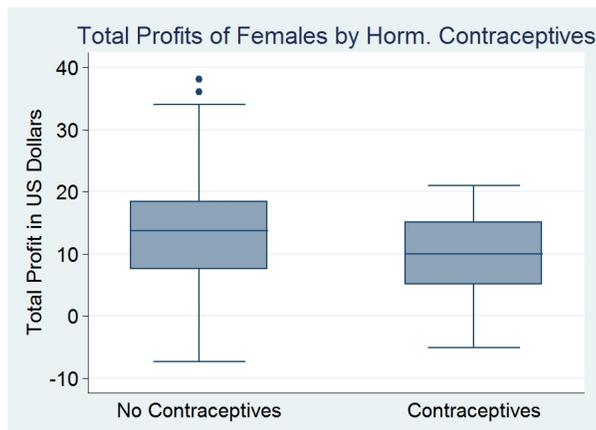
	(Bids3)	(Bids4)	(Profits3)	(Profits4)
Age	0.0120 (0.1399)		-0.0500 (0.2177)	
Num. of Siblings	0.4023* (0.2020)		-0.4614 (0.3792)	
Asian	-1.2374* (0.6647)		1.3542 (0.9348)	
Other	0.1588 (1.3871)		-0.7696 (2.2080)	
GPA	-0.1838 (0.6382)	-0.0593 (0.6216)	0.7132 (0.8142)	0.6859 (0.9125)
Mathematics	-0.5788 (1.4460)		3.4544 (2.0565)	
Science & Engineering	-0.1756 (0.9102)		1.9753 (1.3313)	
Economics	0.7692 (0.7803)		-0.0050 (1.2984)	
Social Science	0.2588 (0.9407)		0.1317 (1.4163)	
Humanities	-0.2341 (1.1388)		0.5816 (1.8615)	
Female	1.7042** (0.7146)	1.3225 (0.8255)	-3.2075*** (1.0139)	-2.8897** (1.0976)
Contraceptives	3.6683*** (1.2029)	3.7957*** (1.2174)	-5.0882** (2.0759)	-5.0966** (1.9277)
<i>Number of Observations</i>	6060	6060	202	202
R^2	0.8597	0.8577	0.2873	0.2562

Robust standard errors (clustered at the session level) in parentheses.

Significance levels: *10%; ** 5%; *** 1%

Not reported: Coefficients of cubic polynomial in values and dummies for bidding rounds (bids), and mean, standard deviation, and skewness of values drawn (profits).

Figure 3: Total Profits of Females by the Use of Hormonal Contraceptives



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.⁹ 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 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

⁹The 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.

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.

Figure 3 shows the box plots of total profits for women by their use of hormonal contraceptives. It suggests that women on hormonal contraceptives may have lower profits. When we control for the use of hormonal contraceptives in specifications “Bids3” and “Profits3”, we observe that women on hormonal contraceptives bid on average 3.7 points higher than white men (Table 3) and earn on average \$5.09 less than white males (when controlling for demographics and GPA). Again, this difference is substantial as it amounts to more than $\frac{1}{3}$ of total earnings. This replicates the finding of Pearson and Schipper (2011) for a subsample of theirs. The finding remains robust if we drop demographics controls in specifications “Bids4” and “Profits4” in Table 3, if we further drop GPA from specifications “Bids4” and “Profits4” (not reported), or add further demographic controls to specifications “Bids3” and “Profits3” (not reported). When we analyze the female subsample separately with specifications analogous to “Bids3” and “Profits4” (not reported), then the use of hormonal contraceptives remains positive and significant for bids ($\beta = 3.68$, $p = 0.009$) but the coefficient for profits is not significant anymore ($\beta = -4.29$, $p = 0.102$). The null-finding with regard to profits may be a Type II error due to the much smaller sample size of 90 women only. If we control for session effects, the coefficient for profits is again significant ($\beta = -5.54$, $p = 0.047$).

Observation 2 (Hormonal Contraceptives) *Females on hormonal contraceptives bid significantly higher and earn significantly lower profits than males.*

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).¹⁰ Hence, one may reasonably expect that the use of hormonal contraceptives would reduce risk-taking, and thus increase bids on average. 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).

While we find the progesterone-GABA-A explanation for the correlation with the use of hormonal contraceptives quite attractive, we cannot claim a causal effect since it may be due to a selection effect. In particular, women who decide to take hormonal

¹⁰We thank Coren Apicella (private communication) for drawing our attention to the connection between progesterone and GABA-A.

contraceptives may also differ systematically in their bidding behavior from women who decide not to take any hormonal contraceptives. It is not clear whether a priori more risk averse women are more likely to use hormonal contraceptives or whether women with more risky sexual behavior are more likely to take hormonal contraceptives.¹¹ 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 from the rest of the population in their risk preferences.

Table 4: 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

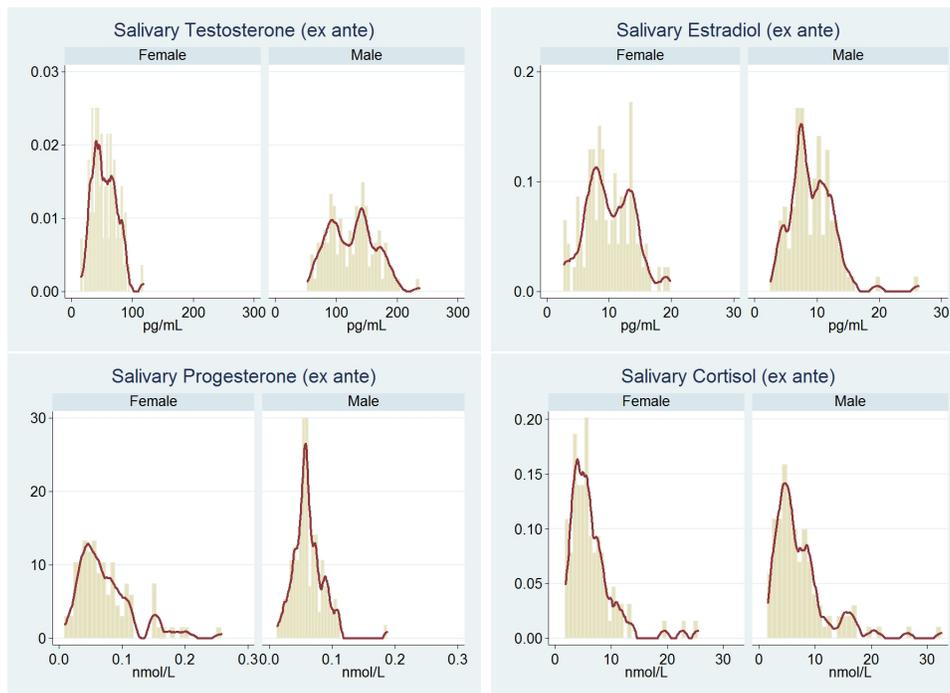
3.3 Ex Ante Salivary Hormones

From each subject we collected saliva after they arrived for the experiment before any behavioral task. 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 salivary hormones. Table 4 provides the summary statistics for salivary hormones by gender and Figure 4 provides histograms and kernel distributions by gender.

Although there is no theory of how salivary hormones should affect bidding behavior, we can derive two quasi-theoretical hypotheses in the case of testosterone (see Figure 5). The first hypothesis explores the risk aversion channel. Both Apicella et al. (2008) and Schipper (2012) find a significant negative correlation between testosterone and risk aversion in choice tasks under risk although Sapienza et al. (2009) and Zethraeus et al. (2009) report null findings. The effects of risk aversion in first-price auctions with symmetric independent private values are well established in theory (see Krishna, 2002, Chapter 4.1). Risk aversion increases equilibrium bids above risk-neutral Nash equilibrium. A higher bid translates into a higher probability of winning the auction, but it also leads

¹¹Schipper (2012) presents some evidence showing that in the current subsample more “consistent” choices of females using hormonal contraceptives in the Holt-Laury lottery choice task may not be due to hormonal contraceptives themselves but to a selection effect.

Figure 4: Densities of Ex Ante Salivary Hormones by Gender

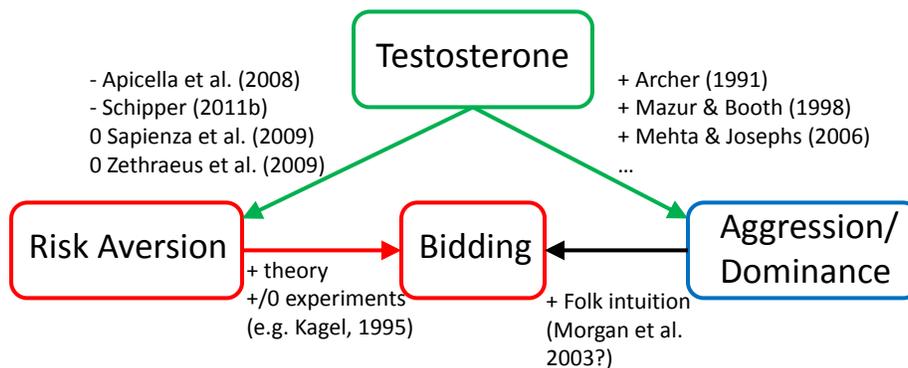


to a lower profit conditional on winning the auction.¹² The experimental evidence for risk aversion in first-price auctions with symmetric independent private values is at best mixed (see for a survey, Kagel, 1995). Nevertheless, this line of reasoning suggests that in theory testosterone should be negatively correlated with bidding in first-price auctions with symmetric independent private values via the risk aversion channel (see the left side of Figure 5).

The second hypothesis with regard to testosterone and bidding explores the aggression/dominance channel. There are ample studies demonstrating a positive correlation between psychological notions of aggression and dominance and testosterone (see Archer, 1991, Dabbs and Hargrove, 1997, Mazur and Booth, 1998, Mehta and Josephs, 2006, etc.). Although there is no theory of how informal notions of “aggression” or “dominance” affects bidding and profits in first-price auctions with symmetric independent private values, “folk” intuition suggests that bidding “more aggressively” means bidding higher. More precisely, “dominance” is often interpreted as “dominance over others” and discussed in an evolutionary context. This is reminiscent of relative payoff concerns. Morgan et al. (2003) show that relative payoff concerns increase bidding in first-price auctions with

¹²We would like to point out though that various dispositions towards uncertainty like anticipate regret from losing the auction (see Filiz and Ozbay, 2007), overconfidence in the winning probability of a bid, ambiguity aversion, etc. lead to similar behavioral predictions in first-price auctions with independent private values.

Figure 5: Two Hypotheses for Testosterone



independent private values. This line of reasoning suggests that testosterone should be positively correlated with bidding in first-price auctions with independent private values via the aggression/dominance channel (see the right side of Figure 5). Thus, we have two opposing hypotheses for how testosterone should affect bidding in our auctions.

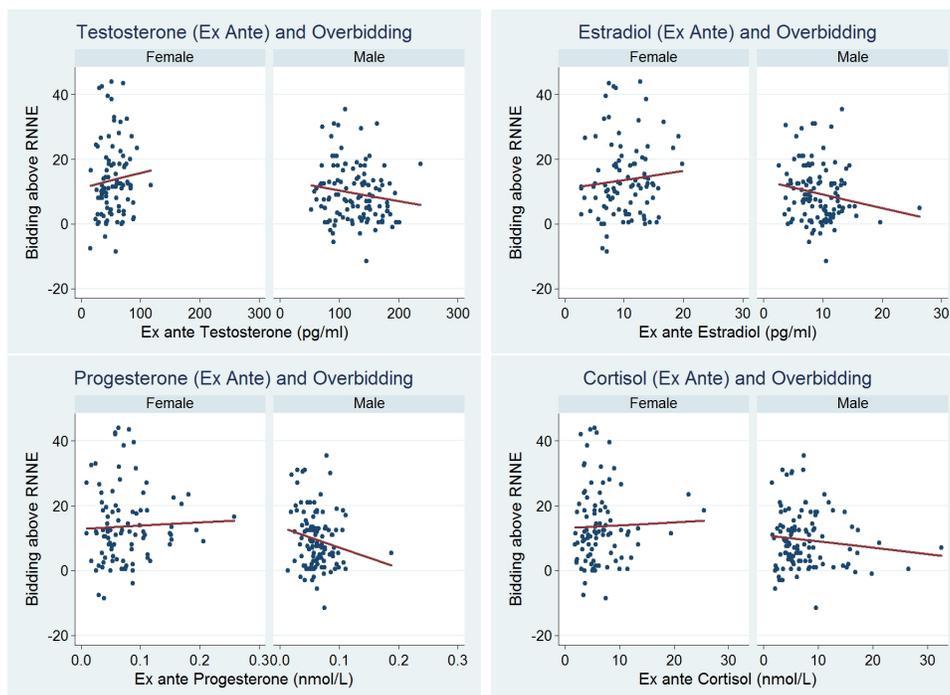
The relationship between ex ante salivary hormones and bidding behavior is preliminarily explored in Figure 6 in which we print by gender for each hormone a scatter plot and fit a linear regression between the hormone level and the difference between observed bids and risk neutral Nash equilibrium bids.

The upper left panel we observe that testosterone may be positively correlated with overbidding, i.e., bidding above risk neutral Nash equilibrium bids, in females but negatively correlated with overbidding in males suggesting that different channels, if any, are at work for males and females.

The upper right panel shows that a similar relationship may hold for estradiol. Although Schipper (2012) did not find a significant correlation between risk aversion and estradiol in both men or women in a choice tasks under risk, this preliminary observation may still be in line with prior evidence since a fraction of testosterone is converted into estradiol in the human body (Mooradian, Morely, and Korenman, 1987). Similar relationships may hold for progesterone (lower left panel) and cortisol (lower right panel) but if there is a relationship, then it appears to be much weaker for females than for males.

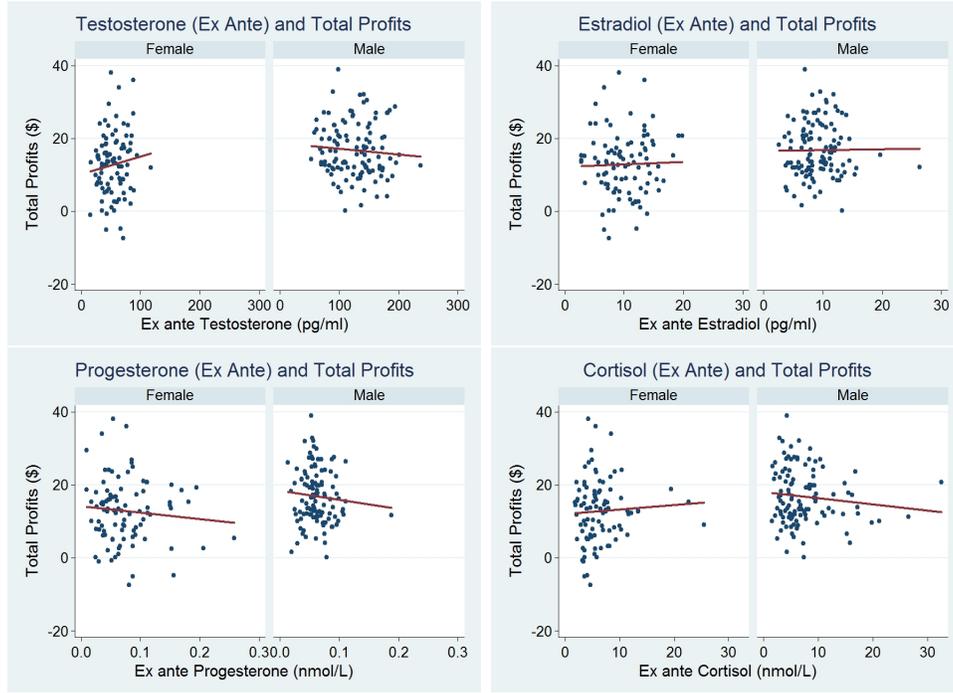
When we turn to total profits in Figure 7, the upper left panel suggests that profits are positively correlated with testosterone in females but negatively correlated in males. No relationship appears for estradiol (upper right panel). A negative correlation between progesterone and profits is observed for both females and males in the lower left panel. Finally, the relationship for cortisol appears to be similar to testosterone. There is a positive correlation between cortisol and profits in females but a negative correlation in males.

Figure 6: Overbidding and Ex Ante Salivary Hormones by Gender



We seek to corroborate these preliminary observations with multivariate regressions that can control also for the use of hormonal contraceptives, gender, and further demographics in Tables 5. We drop one female subject who reported to be pregnant since circulating hormone levels differ during pregnancy, especially with respect to progesterone. Specifications “Bids5” and “Profits5” in Table 5 show null results for the full sample for all salivary hormones except progesterone. One standard deviation of progesterone is associated with an increase of bids by 0.89 points ($p = 0.044$). The coefficients of all other salivary hormones in specification “Bids5” are smaller and insignificant (testosterone: $p = 0.805$, estradiol: $p = 0.196$, cortisol: $p = 0.437$). Nevertheless, their signs are in the “expected” direction. Testosterone and estradiol may be negatively associated with risk aversion and thus negatively correlated with bids similarly for what we see in Figure 6 in the upper left and right panel for males, respectively. With regards to total profits, one standard deviation of progesterone is associated with an increase in total profits by \$1.30 ($p = 0.050$). It is more than 8.6% of average total profits. When we drop controls for demographics, previous observations still obtain but with larger p -values for progesterone ($p = 0.091$ in “Bids6” and 0.090 in “Profits6”). We also obtain marginally significant p -values for progesterone when we add controls for further demographics including body mass index (bmi), sexual preferences, number of dates within the past year, smoking, dietary preferences etc. (not reported). The results for bids but not for profits remain robust when adding session fixed effects to specifications analogous to “Bids6” and “Profits6” (not reported). This may be due to the fact that total profits of subjects also depend

Figure 7: Total Profits and Ex Ante Salivary Hormones by Gender



on other subjects in the session since they play a game and subjects within each session are rematched randomly after each round. Results remain unchanged when controlling for lunch time in specifications analogous to “Bids6” and “Profits6” (not reported) since as discussed in Appendix B the time passed since lunch may effect the quality of saliva. The coefficients of all hormones are insignificant if Bonferroni corrections are made for multiple testing.

Observation 3 (Ex Ante Salivary Hormones - Full Sample) *Bids are significantly positively correlated with salivary progesterone and significantly negatively correlated with salivary progesterone when controlling for gender, the use of hormonal contraceptives, and demographics. The observations become just marginally significant if we don’t control for demographics. The observations are insignificant when Bonferroni corrections are made for multiple testing.*

When we split the sample into females and males, we obtain a similar result for bids of females in specification “BidsF” in Table 6. One standard deviation of progesterone is associated with an increase in bids of 1.05 points ($p = 0.047$). For all other salivary hormones we obtain null results. We also obtain a null result for any salivary hormones and bids in males (specification “BidsM” in Table 6). We note that with respect to testosterone, the sign of the coefficient is unexpectedly positive (but insignificant). None of the salivary hormones is significant for total profits for both females and males in specifications

Table 5: Salivary Hormones, Bids, and Profits

	(Bids5)	(Bids6)	(Profits5)	(Profits6)
Age	0.0503 (0.1393)		-0.0962 (0.2306)	
Num. of Siblings	0.4714** (0.1922)		-0.5288 (0.3735)	
Asian	-1.1527* (0.6505)		1.3013 (0.9168)	
Other	0.0960 (1.3187)		-0.7451 (2.1927)	
GPA	-0.1011 (0.6687)	0.0116 (0.6708)	0.5755 (0.9112)	0.5199 (1.0590)
Mathematics	-0.5319 (1.2260)		3.4672* (1.9042)	
Science & Engineering	0.3513 (0.9958)		1.2118 (1.4123)	
Economics	1.0696 (0.7919)		-0.4753 (1.3339)	
Social Science	0.7832 (1.0470)		-0.5658 (1.5087)	
Humanities	-0.1014 (1.0546)		0.3497 (1.7743)	
Female	1.1868 (1.1798)	0.6258 (1.2894)	-2.9549 (1.9116)	-2.3003 (1.9644)
Contraceptives	4.1410*** (1.2202)	4.1876*** (1.2097)	-5.8478** (2.1859)	-5.8050*** (2.0280)
Testosterone	-0.1280 (0.5139)	-0.2486 (0.5718)	-0.2100 (0.8698)	-0.0178 (0.8884)
Estradiol	-0.4687 (0.3529)	-0.2490 (0.3320)	0.5934 (0.6201)	0.2318 (0.6002)
Progesterone	0.8914** (0.4202)	0.7494* (0.4266)	-1.3027* (0.6327)	-1.1430* (0.6491)
Cortisol	0.2829 (0.3583)	0.1707 (0.3263)	-0.2264 (0.5838)	-0.0941 (0.5400)
<i>Number of Observations</i>	6000	6000	200	200
R^2	0.8608	0.8586	0.3116	0.2803

Robust standard errors (clustered at the session level) in parentheses.

Significance levels: *10%; ** 5%; *** 1%

Not reported: Coefficients of cubic polynomial in values and dummies for bidding rounds (bids), and mean, standard deviation, and skewness of values drawn (profits).

“ProfitsF” and ProfitsM” of Table 6, respectively. There is an insignificant negative correlation between progesterone and total profits in females ($p = 0.147$). If we drop the demographic controls in specification “BidsF”, the coefficient of progesterone becomes insignificant ($\beta = 0.85$, $p = 0.112$). Controlling for session fixed effects in a specification analogous to “BidsF” yields a marginally significant coefficient for progesterone ($\beta = 1.03$, $p = 0.073$). Controlling for lunchtime in a specification analogous to “BidsF” slightly increases the coefficient for progesterone and decreases the p -value (not reported). The

Table 6: Salivary Hormones, Bids, and Profits by Gender

	(BidsF)	(BidsM)	(ProfitsF)	(ProfitsM)
Age	0.1855 (0.1819)	-0.1664 (0.2346)	0.0100 (0.2882)	0.0610 (0.3554)
Num. of Siblings	0.6974* (0.3702)	0.3348 (0.2223)	-1.0139 (0.6095)	-0.3003 (0.4143)
Asian	-1.7073 (1.2233)	-0.9907 (0.9056)	2.5899 (2.1675)	0.9756 (1.3726)
Other	-0.6932 (2.3399)	0.4374 (1.4713)	1.5846 (3.3463)	-1.8884 (2.6877)
GPA	-0.3243 (1.0726)	0.5267 (0.8784)	1.0610 (1.8852)	-0.1435 (1.4365)
Mathematics		-0.3781 (1.2599)		3.8091 (2.3790)
Science & Engineering	-0.8268 (2.0231)	0.8698 (1.0209)	3.7558 (2.6249)	-0.1512 (1.8120)
Economics	-0.0174 (1.6493)	1.7862* (0.9060)	0.6632 (2.6130)	-1.6660 (1.6752)
Social Science	0.3702 (2.1115)	0.8648 (1.0647)	-0.6618 (3.1367)	-0.4076 (1.5533)
Humanities	-0.0973 (1.8103)	0.2832 (1.3258)	1.0188 (2.9355)	-0.4300 (2.1419)
Contraceptives	4.0053*** (1.2960)		-4.1481 (2.6756)	
Testosterone	-0.4672 (1.5135)	0.1047 (0.5063)	1.3043 (2.4861)	-0.4269 (0.7805)
Estradiol	-0.2454 (0.5543)	-0.2838 (0.3788)	0.3835 (1.0491)	-0.0420 (0.6733)
Progesterone	1.0457** (0.5012)	0.1913 (0.5327)	-1.2303 (0.8226)	-0.7102 (0.8408)
Cortisol	0.3516 (0.5174)	0.3786 (0.3846)	0.1867 (0.9463)	-0.6810 (0.6305)
<i>Number of Observations</i>	2670	3330	89	111
R^2	0.8567	0.8711	0.3377	0.2862

Robust standard errors (clustered at the session level) in parentheses.

Significance levels: *10%; ** 5%; *** 1%

Not reported: Coefficients of cubic polynomial in values and dummies for bidding rounds (bids), and mean, standard deviation, and skewness of values drawn (profits).

coefficients of all hormones are insignificant if Bonferroni corrections are made for multiple testing.

Observation 4 (Ex Ante Salivary Hormones by Gender) *Bids are significantly positively correlated with salivary progesterone in females when controlling for the use of hormonal contraceptives and demographics. The observation becomes insignificant if we don't control for demographics. The observation becomes also insignificant if Bonferroni corrections are made for multiple testing. No salivary hormone is significant for bids of males or for profits of females or males.*

3.4 Naturally Cycling Women

The weaker association in the female subsample with respect to profits (as compared to the full sample) may be due to the much smaller sample size. Moreover, 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. Could it be that the weaker findings in the female subsample are due to some confounding effects of hormonal contraceptives on testosterone, estradiol, and progesterone?

We can measure the association of progesterone with bidding and profits in naturally cycling women, i.e., women who do not take hormonal contraceptives, by introducing terms interacting the use of hormonal contraceptives with testosterone, estradiol, and progesterone, respectively. We include them in specifications “NCBids” and “NCProfits” for the female subsample in Table 7 for bids and profits, respectively. The coefficient for progesterone measures now the association between progesterone and bidding (resp. profits) for women who *do not* use hormonal contraceptives, i.e., when the dummy for “Contraceptives” is zero. We observe that an increase of progesterone by one standard deviation in naturally cycling women is associated with an increase of bids by 1.12 points ($p = 0.016$). This is even marginally significant if Bonferroni corrections are made for multiple testing. Similarly, an increase of progesterone by one standard deviation in naturally cycling women is associated with a decrease of total profits by \$1.29 ($p = 0.058$). The coefficient for progesterone is marginally significant when we drop demographic variables in a specification analogous to “NCBids” or add additional demographic variables (not reported). It is significant when we control for lunch time and hence a quality parameter of the saliva ($\beta = 1.21$, $p = 0.014$) (see Appendix B).

In naturally cycling women, progesterone increases sharply after ovulation and falls again before menstruation (see Figure 1). That’s why we would expect the action of progesterone to be more pronounced in the second half of the woman’s menstrual cycle.

We can control for the phase of the cycle by using menstrual cycle information collected in the questionnaire. Besides the number of days past since the beginning of the last menstrual cycle, we also asked for information on the usual length of the menstrual cycle. All 72 naturally cycling women reported also their usual cycle length. There is substantial variability in cycle length. The average is 29.5 days with a standard deviation of 3.24.¹³ We can use this information to construct individualized menstrual cycle phases. Hampson

¹³Regarding 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.

Table 7: Naturally Cycling Females

	(NCBids)	(LutBids)	(NCProfits)	(LutProfits)
Age	0.1976 (0.1820)	0.2004 (0.1854)	-0.0231 (0.2903)	-0.0163 (0.2970)
Num. of Siblings	0.6491 (0.3835)	0.6869* (0.3676)	-0.9151 (0.6696)	-0.9795 (0.6208)
Asian	-2.3094* (1.3234)	-1.7826 (1.2295)	3.4332 (2.3768)	2.6738 (2.1708)
Other	-0.8466 (2.2746)	-0.7404 (2.3452)	1.8738 (3.1710)	1.6438 (3.3556)
GPA	-0.1985 (1.0626)	-0.4187 (1.1380)	0.8211 (1.8881)	1.1755 (1.9718)
Mathematics				
Science & Engineering	-0.6775 (1.9995)	-0.8128 (2.0371)	3.4034 (2.4448)	3.7221 (2.6563)
Economics	0.0891 (1.7573)	-0.0039 (1.6856)	0.4696 (2.6757)	0.6793 (2.7129)
Social Science	0.2806 (2.0073)	0.4604 (2.1331)	-0.6538 (2.9047)	-0.7832 (3.2009)
Humanities	0.5432 (2.1810)	-0.1911 (1.8095)	-0.2438 (3.2771)	1.2222 (2.9322)
Contraceptives	5.0651* (2.6953)	4.2562*** (1.2781)	-7.5235 (4.6337)	-4.6018* (2.6388)
Testosterone	-1.2190 (1.8686)	-0.3564 (1.4997)	2.4656 (2.6996)	1.1346 (2.4494)
Estradiol	0.0210 (0.5884)	-0.2267 (0.5656)	-0.2246 (0.9992)	0.3398 (1.0931)
Progesterone	1.1249** (0.4348)	1.1690** (0.4863)	-1.2875* (0.6469)	-1.4285* (0.7492)
Cortisol	0.4139 (0.4943)	0.3622 (0.5340)	0.0947 (0.9163)	0.1706 (0.9833)
Contracept. x Testost.	8.1220 (4.9980)		-11.9711 (9.0915)	
Contracept. x Estradiol	-2.3648 (1.4067)		4.6299* (2.4895)	
Contracept. x Progest.	-1.1947 (2.2076)		1.0469 (3.5696)	
Contraception or Follicular x Prog.		-0.2745 (0.4371)		0.4417 (0.7388)
<i>Number of Observations</i>	2670	2670	89	89
R ²	0.8583	0.8569	0.3654	0.3405

Robust standard errors (clustered at the session level) in parentheses.

Significance levels: *10%; ** 5%; *** 1%

Not reported: Controls for of cubic polynomial in values and dummies for bidding rounds (bids) and mean, standard deviation, and skewness of values drawn (profits).

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 menstrual cycle phases starting with the last phase. Let y_i be subject i 's 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 *adjusted luteal phase* if and only if $y_i > d_i - 16$. Otherwise, female subject i is said to be in the *adjusted follicular phase*.¹⁴

Next we create an interaction term “(naturally cycling and in the adjusted follicular phase or using hormonal contraceptive) \times progesterone”, in short “Contraception or Follicular \times Prog.”. We include this interaction term in specifications “LutBids” and “LutProfits” in Table 7. The coefficient for progesterone now measures the association of progesterone of naturally cycling women in the *luteal phase* with bids (specification “Lutbids”) or total profits (specification “LutProfits”). We observe that progesterone of naturally cycling women in the luteal phase is positively associated with bids ($p = 0.024$) and negatively associated with profits ($p = 0.068$). The results remains almost unchanged when we also control for lunch time (not reported). When we drop the demographic controls, the observation is marginally significant for bids and insignificant for profits (not reported). It is significant for both bids and profits when session fixed effects considered in specifications analogous to “LutBids” and “LutProfits” (not reported). The result for bids is even Bonferroni-corrected significant if further demographic controls such as BMI, smoking, sexual preferences, dating, and dietary preferences are added, while for profits it is significant but not Bonferroni significant (not reported).

Observation 5 (Naturally Cycling Women) *Bids (resp. profits) are significantly positively (resp. marginally significantly negatively) correlated with salivary progesterone in naturally cycling females when controlling for demographics. Bids (resp. profits) are significantly positively (resp. marginally significantly negatively) correlated with salivary progesterone in naturally cycling females in the luteal phase when controlling for demographics. The last correlation for bids is marginally significant if Bonferroni adjustments are made for multiple testing.*

4 Does Progesterone Effect Bidding through Risk Aversion?

It is not clear why progesterone is positively correlated with bidding in first-price auctions with symmetric independent private values. We are not aware of any prior evidence linking salivary progesterone with either risk aversion or aggression/dominance. To control for risk aversion in our analysis of auctions, we included in our experiments a lottery choice

¹⁴We use here a common definition of menstrual cycle phases similar to Figure 1 with two phases. In Pearson and Schipper (2011) and Schipper (2012) we distinguish between the menstrual phase, follicular phase, peri-ovulatory phase, luteal phase, and the premenstrual phase. Since we are mainly interested in the action of progesterone, the two-phase definition seems more appropriate here.

Table 8: Holt-Laury Lottery Choices in 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 -\$3.20 if throw of die is 2 to 10	-\$7.70 if throw of die is 1 -\$0.20 if throw of die is 2 to 10		-\$2.33
3	-\$4.00 if throw of die is 1 or 2 -\$3.20 if throw of die is 3 to 10	-\$7.70 if throw of die is 1 or 2 -\$0.20 if throw of die is 3 to 10		-\$1.66
4	-\$4.00 if throw of die is 1 to 3 -\$3.20 if throw of die is 4 to 10	-\$7.70 if throw of die is 1 to 3 -\$0.20 if throw of die is 4 to 10		-\$0.99
5	-\$4.00 if throw of die is 1 to 4 -\$3.20 if throw of die is 5 to 10	-\$7.70 if throw of die is 1 to 4 -\$0.20 if throw of die is 5 to 10		-\$0.32
6	-\$4.00 if throw of die is 1 to 5 -\$3.20 if throw of die is 6 to 10	-\$7.70 if throw of die is 1 to 5 -\$0.20 if throw of die is 6 to 10		\$0.35
7	-\$4.00 if throw of die is 1 to 6 -\$3.20 if throw of die is 7 to 10	-\$7.70 if throw of die is 1 to 6 -\$0.20 if throw of die is 7 to 10		\$1.02
8	-\$4.00 if throw of die is 1 to 7 -\$3.20 if throw of die is 8 to 10	-\$7.70 if throw of die is 1 to 7 -\$0.20 if throw of die is 8 to 10		\$1.69
9	-\$4.00 if throw of die is 1 to 8 -\$3.20 if throw of die is 9 or 10	-\$7.70 if throw of die is 1 to 8 -\$0.20 if throw of die is 9 or 10		\$2.36
10	-\$4.00 if throw of die is 1 to 9 -\$3.20 if throw of die is 10	-\$7.70 if throw of die is 1 to 9 -\$0.20 if throw of die is 10		\$3.03

task introduced by Holt and Laury (2002) for the gain domain and by Laury and Holt (2005) for the loss domain. Each lottery choice task consists of a menu of 10 decisions between pairs of lotteries. Table 8 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 8, 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 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 8 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 time, *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.

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

A detailed analysis of the role of salivary sex hormones for risk aversion, reflection (i.e., risk aversion in the gain domain and risk seeking in the loss domain), and “consistency” of choices under risk of our sample in the Holt-Laury lottery task is contained in Schipper

Table 9: Risk Aversion versus Hormones: Full Sample

	(BRisk)	(BRiskHorm)	(PRisk)	(PRiskHorm)
Age	-0.0332 (0.1458)	0.0564 (0.1459)	0.0180 (0.2178)	-0.0956 (0.2262)
Num. of Siblings	0.3645* (0.2061)	0.4661** (0.1995)	-0.4239 (0.3810)	-0.5315 (0.3847)
Asian	-1.5267** (0.6553)	-1.1170* (0.6399)	1.7843* (0.8935)	1.2778 (0.9265)
Other	-0.5013 (1.3578)	0.1234 (1.3263)	0.1629 (2.1888)	-0.7918 (2.1997)
GPA	-0.3921 (0.5949)	-0.1381 (0.6725)	1.0081 (0.8051)	0.6378 (0.9136)
Mathematics	-0.4590 (1.5307)	-0.6962 (1.3532)	3.2407 (2.2387)	3.6285 (2.1531)
Science & Engineering	0.0764 (0.8277)	0.3849 (0.9964)	1.6900 (1.3456)	1.1852 (1.4185)
Economics	0.7890 (0.8481)	1.0162 (0.7845)	-0.0379 (1.5149)	-0.4632 (1.3859)
Social Science	0.7865 (0.9047)	0.8289 (1.0095)	-0.5966 (1.4276)	-0.6510 (1.4549)
Humanities	-0.0961 (1.1724)	0.0113 (1.0564)	0.4185 (1.8520)	0.1770 (1.7632)
Risk Aversion Gains	0.3113 (0.1938)	0.2855 (0.1940)	-0.3747 (0.3087)	-0.3587 (0.3218)
Risk Aversion Losses	-0.0683 (0.3116)	-0.0618 (0.3350)	0.1706 (0.4288)	0.1750 (0.4926)
Female	2.4832*** (0.7215)	1.3224 (1.2002)	-4.2955*** (0.9715)	-3.1467 (1.9106)
Contraceptives		4.2429*** (1.2314)		-5.9806** (2.1953)
Testosterone		-0.0094 (0.5370)		-0.3439 (0.9217)
Estradiol		-0.4870 (0.3703)		0.6034 (0.6621)
Progesterone		0.8565* (0.4250)		-1.2633* (0.6296)
Cortisol		0.2204 (0.3765)		-0.1495 (0.6422)
<i>Number of Observations</i>	6060	6000	202	200
R ²	0.8580	0.8611	0.2637	0.3149

Robust standard errors (clustered at the session level) in parentheses.

Significance levels: *10%; ** 5%; *** 1%

Not reported: Controls for of cubic polynomial in values and dummies for bidding rounds (bids) and mean, standard deviation, and skewness of values drawn (profits).

(2012). Here we will just use the number of choices of option A as a measure of risk aversion as a control in the analysis of bidding and profits in our auctions . In both specification “BRisk” and “PRisk” of Table 9 we add the number of choices of option A in the gain (“Risk Aversion Gains”) and loss (“Risk Aversion Losses”) domains as regressors

to base-line specifications controlling for demographics and gender. We observe that both regressors are insignificant (in “BRisk” $p = 0.121$ and $p = 0.828$ for gains and losses, respectively, and $p = 0.236$ and $p = 0.694$ for gains and losses in “PRisk”, respectively). Nevertheless, the coefficient for risk aversion in the gain domain is positive in specification “BRisk” as one might have expected.

Table 10: Bids: Risk Aversion versus Hormones by Gender

	(RiskFem)	(RiskHormFem)	(RiskMal)	(RiskHormMal)
Age	0.0862 (0.1547)	0.2105 (0.1825)	-0.3041 (0.2364)	-0.2753 (0.2479)
Num. of Siblings	0.4477 (0.4121)	0.6635 (0.4455)	0.3095 (0.2396)	0.3519 (0.2334)
Asian	-2.2854* (1.2155)	-1.4732 (1.1210)	-1.1901 (0.8433)	-1.1678 (0.8862)
Other	-2.4842 (2.4241)	-1.2360 (2.4834)	0.1574 (1.4345)	0.2078 (1.4798)
GPA	-0.5971 (0.9130)	-0.1762 (1.0221)	0.4756 (0.9084)	0.5816 (0.9460)
Mathematics			-0.1900 (1.7591)	-0.3424 (1.4765)
Science & Engineering	-1.0463 (1.8468)	-0.7517 (2.0019)	0.4194 (0.9226)	0.7418 (0.9718)
Economics	-0.6922 (1.7027)	-0.4667 (1.5090)	1.7959* (0.9343)	1.9735* (0.9675)
Social Science	0.7165 (1.8336)	0.1789 (2.0899)	0.6067 (0.9242)	0.9514 (1.0531)
Humanities	-1.3269 (1.5716)	-0.1778 (1.5898)	0.3297 (1.3551)	0.2482 (1.2924)
Risk Aversion Gains	0.4572 (0.4158)	0.4589 (0.4347)	0.2445 (0.2401)	0.2370 (0.2593)
Risk Aversion Losses	0.5313 (0.5473)	0.4377 (0.5661)	-0.6572* (0.3517)	-0.6348 (0.3944)
Testosterone		-0.0866 (1.3466)		0.1490 (0.5013)
Estradiol		-0.3008 (0.5070)		-0.2428 (0.4007)
Progesterone		0.9488* (0.5102)		0.2780 (0.5382)
Cortisol		0.1186 (0.5468)		0.3522 (0.3894)
Contraceptives		4.1407*** (1.3372)		
<i>Number of Observations</i>	2700	2670	3360	3330
R^2	0.8526	0.8581	0.8723	0.8721

Robust standard errors (clustered at the session level) in parentheses.

Significance levels: *10%; ** 5%; *** 1%

Not reported: Coefficients of cubic polynomial in values and dummies for bidding rounds.

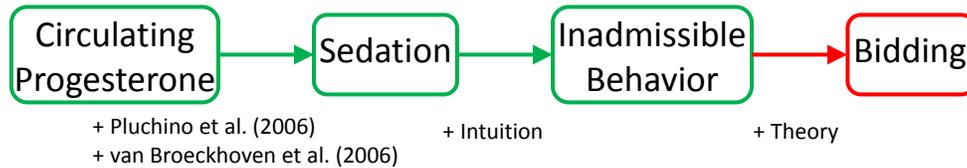
When we add regressors for salivary hormones, we observe in specification “BRiskHorm”

that compared to “Bids5” in Table 5, the coefficient for progesterone does not change much. Yet, it is now only marginally significant ($p = 0.055$). Similarly, we observe in specification “PRiskHorm” that compared to “Profits5” in Table 5, the coefficient for progesterone does decrease only slightly. As in “Bids5”, it is only marginally significant ($p = 0.056$). Similar findings obtain in Tables 10 and 11 when we split the sample in females and males. Adding controls for risk aversion do not change our conclusions drawn previously from Table 6. Yet, the coefficient for progesterone in specification “RiskHormFem” in Table 10 on bids for females declines slightly and becomes just marginally significant ($p = 0.075$). When we add controls for risk aversion to our robustness checks like dropping or adding demographic variables, session fixed effects, and adding lunch time as control, our observations in the previous sections do not change qualitatively.

Schipper (2012) observed that risk aversion in the gain domain for choice under risk is significantly positively correlated with testosterone in the overall sample and in males only even if p -values are Bonferroni-corrected for multiple testing. He found no significant correlation between progesterone and risk aversion. Combining these observations with the findings in the current paper, we conclude that progesterone is unlikely to affect bidding through risk aversion.

Observation 6 (Risk Aversion and Progesterone) *Progesterone does not affect bidding through risk aversion.*

Figure 8: A Hypothesis for Progesterone



5 Imprudent Bidding Behavior

Schipper (2012) finds in our sample that females’ preferences are significantly less accessible than males’ from choice under risk. One reason could be that on average females are significantly less consistent in their choices under risk than males. He does not find a significant positive correlation between progesterone and “consistency” though. As we mentioned earlier in the text, Casari, Ham, and Kagel (2007) report that initially women bid significantly higher than men and thus are more prone to the winner’s curse in common value first-price auctions. However, women also learn bidding much faster than men, thus eventually their earnings may slightly surpass those of the men. Given these findings in the literature, we think it is justified to ask whether our observations with

Table 11: Profits: Risk Aversion versus Hormones by Gender

	(RiskFem)	(RiskHormFem)	(RiskMal)	(RiskHormMal)
Age	0.0744 (0.2538)	-0.0232 (0.2852)	0.1724 (0.3532)	0.1907 (0.3653)
Num. of Siblings	-0.7418 (0.6058)	-0.9541 (0.7126)	-0.3276 (0.4602)	-0.3340 (0.4355)
Asian	3.3162 (1.9691)	2.2530 (2.1588)	1.1056 (1.2777)	1.1781 (1.3328)
Other	3.2916 (3.2773)	2.1805 (3.5509)	-1.4589 (2.5950)	-1.4844 (2.6616)
GPA	1.2384 (1.6315)	0.8549 (1.8093)	0.2765 (1.4051)	-0.2120 (1.5629)
Mathematics			3.5278 (2.8770)	3.6388 (2.6004)
Science & Engineering	4.2938 (2.7042)	3.6255 (2.4867)	0.4324 (1.6896)	0.0121 (1.7031)
Economics	1.7853 (2.7229)	1.2106 (2.4628)	-1.4390 (1.7010)	-1.8940 (1.7531)
Social Science	-0.9560 (2.6627)	-0.4125 (3.0661)	-0.2537 (1.4735)	-0.4613 (1.5539)
Humanities	2.2415 (2.3612)	1.1484 (2.6675)	-0.7066 (2.3369)	-0.2793 (2.0584)
Risk Aversion Gains	-0.4190 (0.6793)	-0.5645 (0.8028)	-0.2053 (0.4042)	-0.1547 (0.4644)
Risk Aversion Losses	-0.6481 (0.8051)	-0.4896 (0.9678)	0.6951 (0.6010)	0.7602 (0.6638)
Testosterone		0.8755 (2.3652)		-0.4099 (0.8516)
Estradiol		0.4214 (1.0985)		-0.0893 (0.7195)
Progesterone		-1.1151 (0.8388)		-0.8343 (0.8121)
Cortisol		0.4754 (1.0761)		-0.6752 (0.6772)
Contraceptives		-4.3970 (2.8731)		
<i>Number of Observations</i>	90	89	112	111
R ²	0.2821	0.3508	0.2745	0.2966

Standard errors (clustered at the session level) in parentheses.

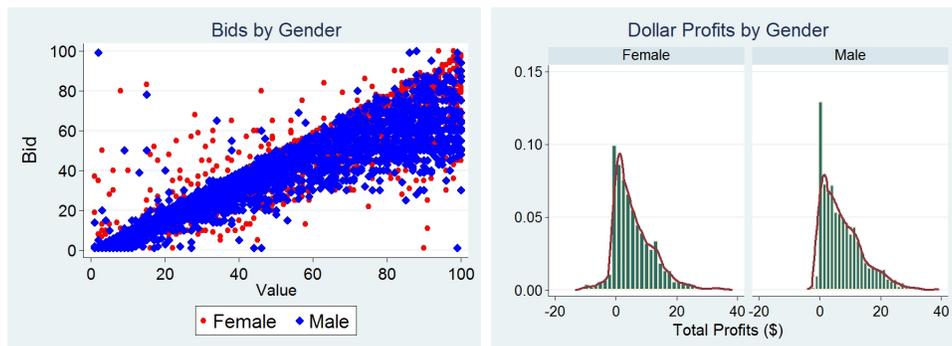
Significance levels: *10%; ** 5%; *** 1%

Not reported: Controls for mean, standard deviation, and skewness of values drawn.

respect to progesterone could be due to less “consistent” behavior (especially in earlier periods of the game) of females in auctions.

To derive a quasi-theoretical hypothesis of the effect of progesterone on bidding via “mistakes”, recall that 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). Intuition suggests that a slight sedation may be positively

Figure 9: Bids and Profits by Gender



correlated with “mistakes”. A “mistake” in the context of first-price auctions with symmetric independent private values is a bid that if winning results in a loss. Any bid above the bidder’s valuation results in a loss if the bid is the winning bid. Such a bid is weakly dominated/inadmissible by bids below the bidder’s valuation. This implies that on average more “mistakes” increase bidding (see Figure 8).

In the left panel of Figure 6 we present a scatter plot of bids and values by gender. The red circle-shaped dots belong to females, while the blue diamond-shaped dots indicate bids by males. The x-axis indicates the value for the object, while the y-axis denotes the bid. If all bidders were to maximize absolute profits, then we should not see any bids above the 45° line. We see more red dots above the 45° line than blue dots suggesting that more females use weakly dominated bids than males. Most of the weakly dominated bids are submitted during the first rounds of the auction and bidders may learn over time that such bids are not profit maximizing. In the right panel of Figure 6 we have drawn histograms and densities of total dollar profits by gender. Again, we see that a larger fraction of females than males earn negative profits which of course are due to weakly dominated bids.

We say a bidder is *imprudent* if (s)he bids above her/his valuation in at least one of the auction rounds, 1 to 30. Otherwise, we call the bidder prudent. While sufficient risk aversion implies bidding above risk neutral Nash equilibrium, a risk averse bidder will never bid above her valuation since with any bid above her valuation she takes the risk of loosing the difference between her bid and her valuation. A bid above her valuation is weakly dominated, inadmissible, and thus not rationalizable by any prudent or cautious belief (i.e., full support belief) over opponent’s bids. That’s why we call this behavior imprudent. In our sample, 23 out of 93 females (25%) are imprudent, while only 20 out of 114 males (17.5%) are imprudent.

To analyze whether our observations with respect to progesterone may be due to imprudent bidders, we interact salivary hormone variables with a dummy variable for being an imprudent bidder. In Tables 12 and 13 we include these variables in regression specification “Hormones” on bids and profits, respectively. The coefficient for salivary

Table 12: Effect of Salivary Hormones, Contraceptives and Gender on Bids for Rationalizable Bidders

	(Hormones)	(Gender)	(Pill)
Age	0.0419 (0.1495)	-0.0627 (0.1359)	0.0136 (0.1426)
Num. of Siblings	0.4016* (0.2046)	0.3552 (0.2133)	0.3778* (0.2044)
Asian	-1.3791* (0.6789)	-1.5371** (0.6632)	-1.2173* (0.6748)
Other	-0.1863 (1.1585)	-0.2107 (1.2515)	0.3073 (1.3891)
GPA	-0.1182 (0.5234)	-0.2906 (0.5260)	-0.0819 (0.6134)
Mathematics	-0.3286 (1.0959)	-0.3378 (1.3274)	-0.6476 (1.4167)
Science & Engineering	0.5893 (0.8797)	0.3311 (0.7690)	-0.1430 (0.8825)
Economics	0.8024 (0.7224)	0.5763 (0.7477)	0.6849 (0.7387)
Social Science	0.3401 (0.9236)	0.3048 (0.7948)	0.0486 (0.8772)
Humanities	-0.1813 (0.9425)	-0.5216 (1.1053)	-0.3393 (1.1028)
Female	1.0555 (1.2330)	1.3365 (0.8009)	1.6806** (0.7117)
Testosterone	0.0132 (0.4688)		
Estradiol	-0.2648 (0.3613)		
Progesterone	0.2488 (0.4448)		
Cortisol	0.4095 (0.3374)		
Contraceptives	3.4923*** (1.0337)		2.3724* (1.1681)
Imprudent x Testost.	-1.2615 (1.0189)		
Imprudent x Estradiol	1.1701 (0.7078)		
Imprudent x Progest.	0.8534 (0.7758)		
Imprudent x Cortisol	0.5710 (0.7634)		
Imprudent x Female		4.6724*** (1.5481)	
Imprudent x Contracept.			4.0986* (2.0387)
<i>Number of Observations</i>	6000	6060	6060
R ²	0.8645	0.8610	0.8604

Robust standard errors (clustered at the session level) in parentheses.

Significance levels: *10%; ** 5%; *** 1%

Not reported: Coefficients of cubic polynomial in values and dummies for bidding rounds.

Table 13: Effect of Salivary Hormones, Contraceptives and Gender on Profits for Prudent Bidders

	(Hormones)	(Gender)	(Pill)
Age	-0.0776 (0.2141)	0.0482 (0.1821)	-0.0524 (0.2218)
Num. of Siblings	-0.4139 (0.3923)	-0.4065 (0.3878)	-0.4273 (0.3806)
Asian	1.7780* (0.9751)	1.7615* (0.8791)	1.3245 (0.9801)
Other	-0.2720 (1.9102)	-0.2110 (2.0212)	-1.0026 (2.2221)
GPA	0.4499 (0.7489)	0.8317 (0.6731)	0.5611 (0.7781)
Mathematics	2.9641 (1.8423)	3.1960 (1.9681)	3.5292* (2.0086)
Science & Engineering	0.9476 (1.1915)	1.3611 (1.2486)	1.9192 (1.3521)
Economics	0.1556 (1.2887)	0.4458 (1.4026)	0.1166 (1.2911)
Social Science	0.2162 (1.1950)	0.1646 (1.2880)	0.4722 (1.3683)
Humanities	0.7907 (1.6726)	1.1164 (1.8160)	0.7392 (1.8476)
Female	-2.7133 (2.0593)	-2.4853** (1.1277)	-3.1711*** (1.0035)
Testosterone	-0.3087 (0.8444)		
Estradiol	0.3456 (0.5854)		
Progesterone	-0.5067 (0.7425)		
Cortisol	-0.4291 (0.5411)		
Contraceptives	-4.6618** (1.9755)		-2.9743 (1.9471)
Imprudent x Testost.	1.1652 (1.5832)		
Imprudent x Estradiol	-1.9769 (1.3097)		
Imprudent x Progest.	-0.8345 (1.3457)		
Imprudent x Cortisol	-0.8674 (1.3907)		
Imprudent x Female		-6.8783*** (2.4652)	
Imprudent x Contracept.			-6.6405* (3.5560)
<i>Number of Observations</i>	200	202	202
R ²	0.3868	0.3113	0.3017

Robust standard errors (clustered at the session level) in parentheses.

Significance levels: *10%; ** 5%; *** 1%

Not reported: Controls for mean, standard deviation, and skewness of values drawn.

hormone variables now measures the association of salivary hormones on bids and profits, respectively, for prudent bidders only. We clearly observe a null result. Compared to specifications “Bids5” and “Profits5” in Table 5, we note that the coefficients for progesterone are much smaller and insignificant ($p = 0.659$ and $p = 0.468$ for bids and profits, respectively). Thus, we conclude that our prior findings with respect to progesterone are mainly driven by bidders who sometimes submitted bids above their valuation.

We can also ask whether gender differences could be due to imprudent bidders in our sample. In specifications “Gender” of Tables 12 and 13 we interact the dummy for imprudent bidders with the dummy for being female and add them to regressions on bids and profits, respectively. The coefficient for being female now measures the effect of being female for prudent bidders only (i.e., if imprudence is null). Again, we obtain a null result. Compared to “Bids1” and “Profits1” in Table 2, the coefficients for the gender dummy are now much smaller. For bids it is insignificant and for profits it is marginally significant ($p = 0.123$ and $p = 0.052$ for bids and profits, respectively). Thus, we conclude that our prior findings on the gender effect may be to a large extent due to imprudent bidders.

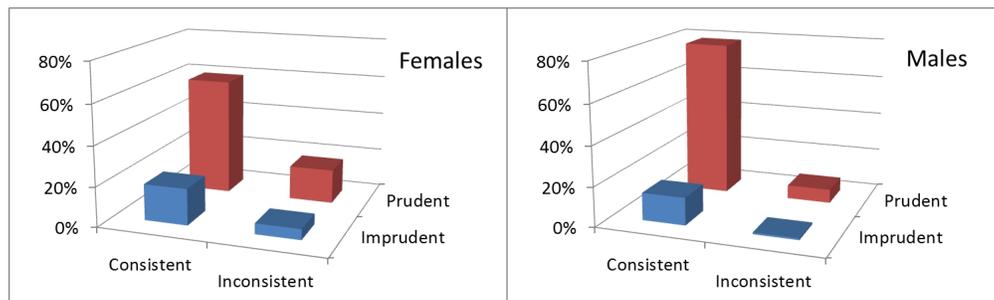
Finally, we analyze whether the finding with respect to the use of hormonal contraceptives may be due to imprudent bidders in our sample. In specifications “Pill” of Tables 12 and 13 we interact the dummy for imprudent bidders with the dummy for the use of hormonal contraceptives and add them to regressions on bids and profits, respectively. The coefficient for using hormonal contraceptives now measures the effect of using hormonal contraceptives for prudent bidders only (i.e., if imprudence is null). Again, compared to “Bids 3” and “Profits3” in Table 3, the coefficients for using hormonal contraceptives are reduced in size. For bids it is marginally significant ($p = 0.053$) but for profits it is insignificant ($p = 0.139$). Thus, we conclude that our prior findings on the use of hormonal contraceptives may be to a large extent due to imprudent bidders.

Observation 7 (Imprudent Bidders) *Our previous observations with respect to gender, the use of hormonal contraceptives, and salivary progesterone are likely to due imprudent bidders, i.e., bidders that bid above their valuation at some point during the repeated auction game.*

We do not know why bidders submitted weakly dominated bids. It could be due to misunderstandings of the rules of the game. But we like to stress that we carefully explained the auction game to all participants and tested their understanding of how payoffs are determined (see Appendix D). There are alternative explanations for bidding above your valuation. In particular, bidding above your valuation may be rationalizable under particular utility functions of bidders. For instance, some subjects may be sometimes motivated by “joy-of-winning”.

Finally, we like to remark that imprudence in the auction game seems to be unrelated to “inconsistency” for choice under risk as analyzed in Schipper (2012). Not all subjects may display an unique cut-off for switching between the options but may switch several

Figure 10: Prudence in Auctions vs. “Consistency” under Risk by Gender



times between options A and B in the Holt-Laury lottery task.¹⁵ 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 domains, respectively. This is inconsistent with maximizing expected monetary payoff irrespective of the risk attitude. We say that a subject is “consistent” if she has an unique cut-off for switching between options and respects dominance. Figure 10 shows that for both females and males, imprudence in auctions is not necessarily correlated with “inconsistency” of choice under risk.

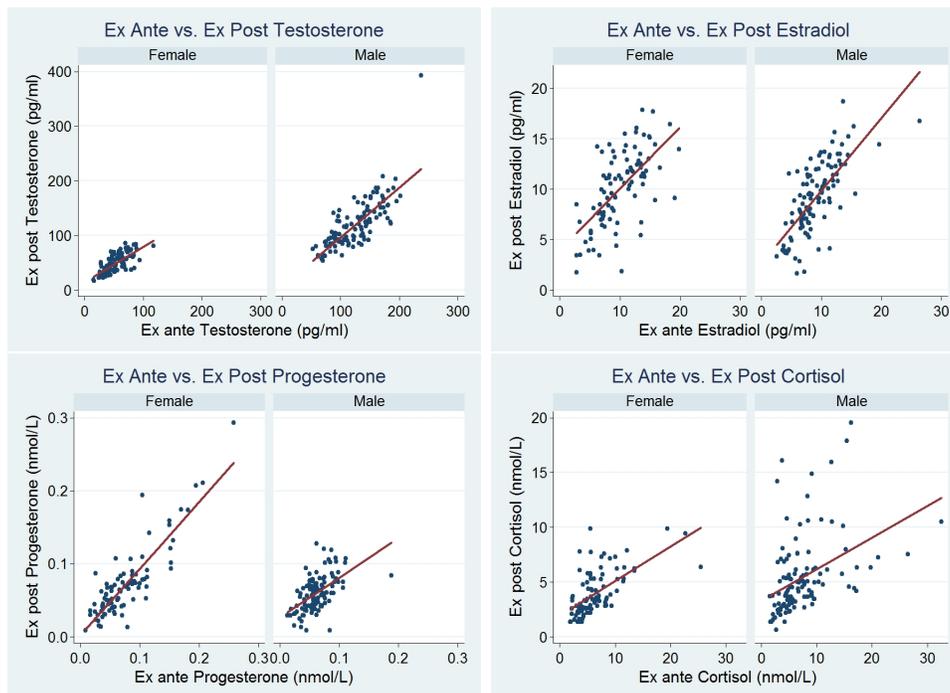
6 Ex Post Salivary Hormones

At the very end of the experiment, we collected a second saliva sample from subjects. This is about 20 to 30 minutes after the auction task and more than one hour after the first saliva sample. The rationale for the second saliva sample is that various hormones may respond to events in the experiment. In particular, we are interested in how total profits earned by subjects may effect salivary hormones. The previous literature found effects of events on salivary hormones about 15 to 30 minutes after the events occurred (see Schultheiss et al., 2005, Kivlighan, Granger, and Booth, 2005, Edwards and O’Neal, 2009, Saad and Vongas, 2009). For instance, Saad and Vongas (2009) observed increased salivary testosterone levels in men 30 minutes after driving an expensive convertible sports car. Besides testosterone, we would expect that cortisol, the stress hormone, may increase with the anxiety or excitement generated in the auction game. However, this effect may be partially countered by the circadian cycle of cortisol. Cortisol declines over the afternoon.

Figure 11 shows scatter plots correlating ex ante salivary hormones with ex post salivary hormones by gender. We don’t recognize any obvious changes in salivary hormones except for cortisol. In some subjects, cortisol seem to respond positively while in others cortisol declines over the duration of the experiment.

¹⁵This may not be due to “mistakes” but could be due to indifferences. That’s why Schipper (2012) calls those preferences more appropriately “inaccessible”.

Figure 11: Ex Ante vs. Ex Post Salivary Hormones

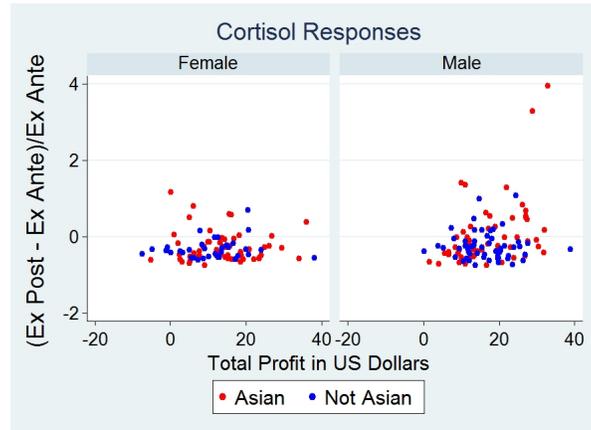


In order to analyze whether cortisol responses may be due to total dollar profits in the experiment, we present in Figure 12 a scatter plot showing the association between total dollar profits and the change of cortisol in percentage of ex ante cortisol by gender. We can not recognize a systematic relationship. Yet, a few subjects with higher profits seem to respond strongly. To learn more about those subjects, we indicated with red dots asian subjects. At appears to us that those extreme respondents are mostly asian. Among the females we also noticed a few asian females that respond slightly stronger than others and have relatively low total dollar profits. While we find these preliminary observations interesting, our data do not allow us to substantiate any strong regularities of cortisol responses.

7 Conclusions

Our main finding is that bidding is positively correlated with progesterone when controlling for gender and further controls. This applies also separately to the female subsample but not to the male subsample. It especially applies to natural cycling females who do not use hormonal contraceptives. This main finding is consistent with prior observations of bidding and profits in first-price auctions over the menstrual cycle that used self-reported menstrual cycle information (Pearson and Schipper, 2011). Progesterone is the steroid

Figure 12: Cortisol Responses



hormone whose changes is most pronounced during the menstrual cycle (see for instance, Chatterton et al., 2005). Our finding is also consistent with substantial gender differences in bidding in first-price auctions (Casari, Ham, and Kagel, 2007, Ham and Kagel, 2006, Chen, Katuščák, and Ozdenoren, 2009, Pearson and Schipper, 2011). Interestingly, we observe that progesterone does not seem to correlate with bidding via risk aversion, despite the fact that there is a literature on gender differences in risk aversion (for surveys, see Croson and Gneezy, 2009, Eckel and Grossman, 2008a, Byrnes, Miller, and Schafer, 1999). This finding adds another piece of evidence to the experimental auction literature that risk aversion may not play a prominent role in auction behavior. However, we observe that progesterone is correlated with imprudent bidding behavior. We hypothesize that this is due to the sedating effect of progesterone. Our finding with regard to progesterone is also consistent with our finding on the use of hormonal contraceptives. Women on hormonal contraceptives bid significantly higher and earn significantly lower profits than men. All hormonal contraceptives contain progestin, a synthetic version of progesterone. The correlation between bidding and the use of hormonal contraceptives has the same sign as the correlation between bidding and salivary progesterone. Yet, we like to point out that we cannot exclude that the correlation between bidding and the use of hormonal contraceptives is due to a selection effect rather than a causal effect of progestin.

Most surprising is our null result for testosterone. We do not find any significant correlation between bidding (or profits) and salivary testosterone. This is despite the fact of replicated experimental evidence showing a negative association between testosterone and risk aversion (see Apicella et al., 2008, and Schipper, 2012) and the clear theoretical prediction of risk aversion in first-price auctions with symmetric independent private values. Again, this underlies the claim that risk aversion may not play a prominent role in experimental auction behavior. We also obtain null results for estradiol and cortisol.

Whether to accept our evidence as sufficient depends on the preferences over the trade-off between false positives and false negatives. First, we should admit that the

size of the correlation between bidding and progesterone is not very large. Second, our analysis involves multiple testing of four hormones. We choose a level of $\alpha = 0.05$ to claim significance. If we were to focus on one particular hormone x from the beginning of the design of our study, we can take α to be the probability of a false positive, i.e., the probability of falsely claiming that hormone x is correlated with bidding. Then $1 - \alpha$ is the probability of true positive, i.e., the probability of correctly claiming that hormone x is correlated with bidding. However, we included four hormones into our study. Suppose that tests for our four hormones were independent. Then the probability of correctly claiming that each of our four hormones is correlated with bidding is $(1 - \alpha)^4 \approx 0.816$. It follows that the probability that at least one of the claims is false is $1 - (1 - \alpha)^4 \approx 0.184$! That is, the probability of claiming a false positive observation for a hormone would be almost four times of our desired false positive rate of 5%.¹⁶ We use Bonferroni correction to correct for multiple testing. It simply requires significance level of $\frac{\alpha}{4}$ when four hormones are tested. That is, our Bonferroni corrected significance level would be 1.25% instead of 5%. Note, however, that Bonferroni correction is very conservative as it implicitly assumes independence of tests of all four hormones, but the tests of our hormones are likely to be correlated due to steroidogenesis, i.e., the transformation of one steroid hormone into another. All steroid hormones are synthesized from cholesterol (via intermediate steps). The Bonferroni correction reduces the probability of a false positive finding for a hormone but for a given sample size it also increases the probability of a false negative finding, i.e., falsely claiming that a hormone is not correlated with bidding. There is no procedure to resolve this trade off for a given sample size. By reporting throughout the paper significance using Bonferroni correction for multiple testing in addition to the ordinary significance levels, we provide an idea for the range of the trade-off between false positives and false negatives.

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¹⁶A similar problem occurs if a study collects different measurements but chooses ex post to report only on positive findings and keeps silent on 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 17β -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 1). 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, $C_{21}H_{30}O_2$, 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 1) 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 know 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°C till the end of March 2010 and then at -80°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°C over a period of 36 months. The same applies for samples collected in the late afternoon and stored at -20°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 17β -estradiol enzyme immunoassay kit (Salimetrics LLC, State College, PA). Assay procedures were run in accordance to manufacturer's protocol HS Salivary 17β -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 μl . 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 μl , 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 F) 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 14, 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 unresponsive to microinjuries in the mouth or teeth brushing. Some of the variables we used in robustness checks of our results.

Table 14: Quality of Salivary Hormones

	(TF)	(TM)	(EF)	(EM)	(PF)	(PM)	(CF)	(CM)
When lunch today	-0.0099 (0.0211)	-0.0703** (0.0295)	-0.0588 (0.0727)	0.0150 (0.0370)	-0.0901 (0.0660)	-0.0220 (0.0210)	-0.0529 (0.0421)	-0.1341** (0.0567)
Time last eaten	-0.0005 (0.0005)	0.0017* (0.0009)	-0.0015 (0.0017)	-0.0002 (0.0009)	-0.0022 (0.0016)	-0.0019*** (0.0007)	-0.0019** (0.0008)	-0.0029* (0.0015)
Time last drunken	-0.0024** (0.0012)	-0.0023 (0.0017)	-0.0046 (0.0029)	0.0013 (0.0017)	-0.0044 (0.0040)	-0.0003 (0.0011)	-0.0035 (0.0022)	0.0007 (0.0020)
Mouth injuries	-0.0571 (0.0963)	0.2321 (0.2340)	-0.2568 (0.3165)	0.0989 (0.2223)	0.1947 (0.4825)	-0.0797 (0.1793)	0.1736 (0.2256)	-0.0773 (0.2193)
Freq. teethbrush.	0.1487 (0.1082)	0.0585 (0.1168)	0.1030 (0.2610)	0.1236 (0.1182)	-0.5213 (0.3491)	0.1655* (0.0974)	-0.0380 (0.1452)	0.3596** (0.1580)
Time last teethbrush.	-0.0026 (0.0044)	-0.0047* (0.0024)	0.0020 (0.0054)	-0.0088** (0.0040)	-0.0027 (0.0040)	-0.0047*** (0.0017)	-0.0116 (0.0070)	0.0003 (0.0029)
Smoking	0.0495 (0.1096)	0.1046 (0.1305)	0.4001 (0.2703)	0.4167** (0.1969)	0.1090 (0.2889)	0.0999 (0.1124)	-0.0564 (0.2054)	0.1444 (0.2353)
Daylight Sav. Time	0.2276 (0.2136)	-0.1032 (0.2632)	0.3933 (0.6583)	0.1314 (0.3033)	0.3975 (0.8050)	0.0109 (0.1330)	1.5397* (0.8122)	-0.1674 (0.2983)
<i>Number of Observations</i>	93	115	93	115	93	114	93	114
<i>R²</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)

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

Decision used: _____ Die throw: _____

Your earnings on this sheet: _____

Decision Sheet (Losses)

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

Decision used: _____ Die throw: _____

Your earnings on this sheet: _____

D Instructions for the Auctions

Introduction

You are about to participate in a decision process in which an imaginary object will be auctioned off for each group of participants in each of 30 rounds. This is part of a study intended to provide insight into certain features of decision processes. If you follow the instructions carefully and make good decisions you may earn a bit of money. You will be paid in cash at the end of the experiment.

During the experiment, we ask that you please do not talk to each other. If you have a

question, please raise your hand and an experimenter will assist you.

You may refuse to participate in this study. You may change your mind about being in the study and quit after the study has started.

Procedure

In each of 30 rounds, you will be *randomly* matched with one other participant into a group. Each group has two bidders. You will not know the identity of the other participant in your group. Your payoff each round depends **ONLY** on the decisions made by you and the other participant in your group.

In each of 30 rounds, each bidder's value for the object will be randomly drawn from 1 of 2 distributions:

High value distribution: If a bidder's value is drawn from the high value distribution, then

- with 25% chance it is randomly drawn from the set of integers between 1 and 50, where each integer is equally likely to be drawn.
- with 75% chance it is randomly drawn from the set of integers between 51 and 100, where each integer is equally likely to be drawn.

For example, if you throw a four-sided die, and it shows up 1, your value will be equally likely to take on an integer value between 1 and 50. If it shows up 2, 3 or 4, your value will be equally likely to take on an integer value between 51 and 100.

Low value distribution: If a bidder's value is drawn from the low value distribution, then

- with 75% chance it is randomly drawn from the set of integers between 1 and 50, where each integer is equally likely to be drawn.
- with 25% chance it is randomly drawn from the set of integers between 51 and 100, where each integer is equally likely to be drawn.

For example, if you throw a four-sided die, and if it shows up 1, 2 or 3, your value will be equally likely to take on an integer value between 1 and 50. If it shows up 4, your value will be equally likely to take on an integer value between 51 and 100.

Therefore, if your value is drawn from the high value distribution, it can take on any integer value between 1 and 100, but it is three times more likely to take on a higher value, i.e., a value between 51 and 100.

Similarly, if your value is drawn from the low value distribution, it can take on any integer value between 1 and 100, but it is 3 times more likely to take on a lower value, i.e., a value between 1 and 50.

In each of 30 rounds, each bidder's value will be randomly and independently drawn from the high value distribution with 30% chance, and from the low value distribution with 70%

chance. You will not be told which distribution your value is drawn from. The other bidders' values might be drawn from a distribution different from your own. In any given round, the chance that your value is drawn from either distribution does not affect how other bidders' values are drawn.

Each round consists of the following stages:

Bidders are informed of their private value, and then each bidder will simultaneously and independently submit a bid, which can be any integer between 1 and 100, inclusive.

The bids are collected in each group and the object is allocated according to the rules of the auction explained in the next section.

Bidders will get the following feedback on their screen: your value, your bid, the winning bid, whether you got the object, and your payoff.

The process continues.

Rules of the Auction and Payoffs

In each round,

- if your bid is greater than the other bid, you get the object and pay your bid:

$$\mathbf{Your\ Payoff = Your\ Value - Your\ Bid;}$$

- if your bid is less than the other bid, you don't get the object:

$$\mathbf{Your\ Payoff = 0.}$$

- if your bid is equal to the other bid, the computer will break the tie by flipping a fair coin. Such that:

with 50% chance you get the object and pay your bid:

$$\mathbf{Your\ Payoff = Your\ Value - Your\ Bid;}$$

with 50% chance you don't get the object:

$$\mathbf{Your\ Payoff = 0.}$$

There will be 30 rounds. There will be 2 practice rounds. From the first round, you will be paid for each decision you make.

Your total payoff is the sum of your payoffs in the 30 "real" rounds.

The exchange rate is \$1 for 13 points.

We encourage you to earn as much cash as you can. Are there any questions?

Review Questions: Please raise your hand if you have any questions. After 5 minutes we will go through the answers together.

1. Suppose your value is 60 and you bid 62.
If you get the object, your payoff =.
If you don't get the object, your payoff =.
2. Suppose your value is 60 and you bid 60.
If you get the object, your payoff =.
If you don't get the object, your payoff =.
3. Suppose your value is 60 and you bid 58.
If you get the object, your payoff =.
If you don't get the object, your payoff =.
4. In each of 30 rounds, each bidder's value will be randomly and independently drawn from the high value distribution with % chance.
5. Suppose your value is drawn from the low value distribution. With what % chance is the other bidder's valuation also drawn from the low distribution?
6. True or False:
If a bidder's value is 25, it must have been drawn from the low distribution.
If a bidder's value is 60, it must have been drawn from the high distribution.
You will be playing with the same two participants for the entire experiment.
A bidder's payoff depends only on his/her own bid.

E Screen Shots

Period 1 of 1 Remaining time (sec) 25

Your value is **51**.
Please submit a bid (1 - 100):

Round	Value	Your Bid	Bid?	Payoff	Total Payoff
1	51	8	No	0.0	0.0

Period 1 of 1

You **did** get the item.

Your value was: **51**

Your bid was: **23**

The winning bid was: **Your bid**

Your profit is: **28**

F 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? _____