Menstrual Cycle and Competitive Bidding*

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Abstract

In an experiment using two-bidder first-price sealed-bid auctions with symmetric independent private values and 400 participants, we collected information on the female participants' menstrual cycles and the use of hormonal contraceptives. We find that naturally cycling women bid significantly higher than men and earn significantly lower profits than men except during the midcycle when fecundity is highest. We 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, quality of offspring, and genetic variety. We also find that women on hormonal contraceptives bid significantly higher and earn substantially lower profits than men. This may be due to progestins contained in hormonal contraceptives or a selection effect. We discuss how our study differs from Chen, Katuščák, and Ozdenoren (2012).

Keywords: Hormones, Menstrual cycle, Gender, Fecundity, Contraceptives, Pill, First-price auction, Risk behavior, Competition, Bidding, Endocrinological economics.

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

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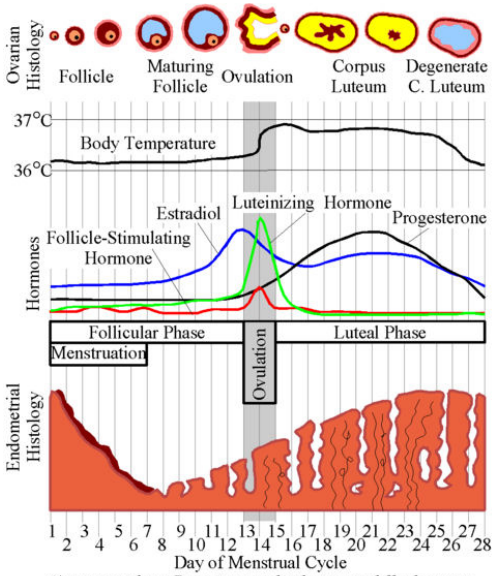
1 Introduction

We are interested to what extent biological factors may explain variations in competitive bidding in auctions. Casari, Ham, and Kagel (2007) report significant 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 the 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 (2012) 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 follicle-stimulating hormone all change over the menstrual cycle (see Figure 1). Thus menstrual cycle information provides relative easy to observe within-female measures of some hormones. Chen, Katuščák, and Ozdenoren (2012) 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. Moreover, for first-price auctions they infer that higher bidding in the follicular phase and lower bidding in the luteal phase are driven entirely by oral hormonal contraceptives.

Figure 1: Menstrual Cycle



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

Higher bidding of women in first-price auctions with independent private values may be due to risk aversion. The effects of risk aversion in this standard auction are well established in theory (see Krishna, 2002, Chapter 4.1). Risk aversion increases equilibrium bids in first-price auctions with independent private values but not in second-price auctions. In first-price auctions with independent private values, 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. In the symmetric equilibrium in weakly dominant strategies of second-price auctions, risk aversion has no effect on bids. Surveying recent experimental and empirical work on gender, risk, and competition, Croson and Gneezy (2009) conclude that despite some caveats there is "clear evidence that men are more risk-taking than women in most tasks and populations" (see also Eckel and Grossmann, 2008) and that on average women prefer less competitive situations than men. We would like to point out though that various dispositions towards uncertainty like anticipated regret from losing the auction (see Filiz and Ozbay, 2007), overconfidence in the winning probability of a bid, ambiguity aversion, joy of winning, relative payoff concerns (Morgan et al., 2003) etc. lead to similar behavioral predictions in first-price auctions with independent private values. Thus, gender or hormones may affect bidding in first-price auctions with independent private values through a number of those dispositions that are behaviorally indistinguishable from risk aversion.[1]

To our knowledge, Chen, Katuščák, and Ozdenoren (2012) is one of the first papers in economics using menstrual cycle information as a proxy for the effect of certain hormones on economic behavior. As such, it warrants an independent replication, which is the goal of our study. Potentially, robust findings on the endocrinology of economic behavior could profoundly influence our understanding of the biological basis of economic outcomes including the gender wage gap (for a survey, see Blau and Kahn, 2000).[2] Our study focuses on the first-price auctions only. We thank Yan Chen for providing us with the z-tree programs of their first-price auctions. The main differences between the designs are as follows: We focus on auctions without ambiguity about the value distribution, collect information on the use of hormonal contraceptives from all female subjects, and use 400 subjects, while Chen, Katuščák, and Ozdenoren (2012) use auctions with ambiguous value distributions in some sessions, collect information on hormonal contraceptives from some female subjects only, and use 160 subjects in the first-price auctions. Yet, they also run treatments with second-price auctions.

Our main findings are as follows: As in Chen, Katuščák, and Ozdenoren (2012) we observe that on average women bid significantly higher than men. However, we find

[1]Therefore, we will use in this paper the term "risk aversion" to refer more generally to any disposition that is behaviorally indistinguishable from risk aversion in first-price auctions. For a discussion of the experimental evidence on risk aversion in first-price auctions we refer to Kagel (1995, Chapter 7 I.G).

[2]Using data from a large Italian bank, Ichino and Moretti (2008) conclude that the women's higher levels of absenteeism in the workplace due to their menstrual cycle explains at least 14% of the gender wage gap. But Rockoff and Hermann (2011) do not find that absenteeism is due to the menstrual cycle for a data set of teachers and show that the result by Ichino and Moretti (2008) is not robust to the correction of coding errors.

that *naturally cycling* women bid significantly higher than men and earn significantly lower profits than men except during the midcycle when fecundity is highest. For the interpretation of our results, we suggest an evolutionary hypothesis: Women are influenced by hormones to behave generally more riskily during the fecund phase of their menstrual cycle in order to increase (possibly also through infidelity) the probability of conception, quality of offspring, and genetic variety. We also find that women who take hormonal contraceptives bid significantly higher and earn significant lower profits than men. We discuss our results and the differences to Chen, Katuščák, and Ozdenoren (2012) in Section 4.

Chen, Katuščák, and Ozdenoren (2012) and our study can be seen as taking part in a larger recent research program that may be termed "endocrinological economics". It is known that various hormones regulate behavior to some extent (Nelson, 2011). To better understand human nature with regard to economic activities, it is of interest to investigate to what extent hormones may determine economic behavior. There is a small but increasing literature studying the relationship between hormones and economic behavior. This literature uses either (1) indirect measures of hormones such as the menstrual cycle, (2) indirect measures of prenatal exposure to hormones like the digit ratio, (3) direct measurements of hormones in saliva or blood plasma, or (4) experiments with placebo-controlled administration of hormones. As an example of the first type of studies, Wozniak, Harbaugh, and Mayr (2010) study the correlation between the selection into tournaments with either piece-rate and winner-take-all compensation a là Gneezy, Niederle, and Rustichini (2003) and Niederle and Vesterlund (2007) and the menstrual cycle. They find that women early in their menstrual cycle are relatively more reluctant to choose winner-take-all compensation than women later in their menstrual cycle. No such differences (also no differences between men and women) are observed when participants receive feedback about their relative performance. In an all-female sample, Buser (2012a) comes to a different conclusions. He observes that women later in their menstrual cycle are relatively more reluctant to choose winner-take-all compensation. Buser (2012b) studies the correlation between social preferences and the menstrual cycle. Women give significantly less than men in a trust game but not during the midcycle. Moreover, women are more likely than men to pick equal allocations in a dictator game in the luteal phase only and return a higher proportion than men in the trust game during the luteal phase only. Women also offer significantly more than men in an ultimatum bargaining game during the midcycle only and reject significantly less often during the midcycle only. Finally, women contribute significantly more than men to a public good during menstruation.

Studies of prenatal exposure to sex hormones employ mainly the digit ratio (2D:4D), the ratio between the length of the pointer and the ring fingers, as an easy to observe marker. 2D:4D is believed to be positively correlated with prenatal exposure to estrogen and negatively correlated to prenatal exposure to testosterone (Manning et al., 1998, Lutchmaya et al., 2004, Hönekopp et al., 2007). Dreber and Hoffman (2007) and Garbarino et al. (2011) show that risk-taking in an investment task is significantly negatively correlated with 2D:4D in White subjects but Apicella et al. (2008) and Schipper (2012b)

show that this is not the case in ethnically more mixed samples. Sapienza et al. (2009) do not find a significant correlation between risk aversion and 2D:4D in a lottery choice task except for a marginal significant positive correlation for females in a sample of 550 MBA students. Coates, Gurnell, and Rustichini (2009) find that lower 2D:4D predicts the 20-month average profitability of 44 male high-frequency traders in London. In a companion paper using the same sample as in the current paper, Pearson and Schipper (2012) do not find a significant correlation of both competitive bidding and profits with 2D:4D in sealed-bid first-price auctions. Van den Bergh and Dewitte (2006) report that in ultimatum bargaining games men with lower 2D:4D are more likely to reject unfair offers in neutral contexts but are morel likely to accept unfair offers in sex-related contexts. Using a public good game, Millet and Dewitte (2006) find that men and women with lower digit ratios contribute proportionally, whereas those with higher 2D:4D contributed either more or less. Sanchez-Pages and Turiegano (2011) show that men with intermediate 2D:4D are more likely to cooperate in a one-shot prisoners' dilemma game.

The effect of circulating hormones on economic behavior has also been studied using direct measures of sex hormones. Apicella et al. (2008) find that risk-taking in an investment decision is positively correlated with salivary testosterone levels in men. Yet, Sapienza et al. (2009) found only a non-significant negative correlation between salivary testosterone and risk aversion in MBA students. Using about half of the sample studied in the current paper, Schipper (2012b) finds a significant positive correlation between salivary testosterone and risk-taking in men but not in women in Holt-Laury lottery tasks for gains. However, risk-taking in women is marginally significantly negatively correlated with salivary cortisol. No correlations are found for estradiol and progesterone. Moreover, no significant correlations are found between any of the four steroid hormones and choice under risk in the loss domain. Burnham (2007) shows that men with high salivary testosterone are more likely to reject low offers in an ultimatum bargaining game. Sanchez-Pages and Turiegano (2011) found no correlation of salivary testosterone and cooperation in a one-shot prisoners' dilemma. Zak, Kurzban, and Matzner (2005) report that blood plasma levels of oxytocin are positively correlated with trustworthy behavior in a trust game. Zak, Kurzban, and Matzner (2004) mention that ovulating women are also statistically less trustworthy, where ovulation is established with a progesterone-based indicator from blood plasma. Johnson et al. (2006) find no evidence that subjects with higher levels of salivary testosterone were more likely to make unprovoked attacks in a war game. Using a subsample of the current paper, Schipper (2012a) reports that bidding is significant positively correlated with salivary progesterone and profits are significantly negatively correlated with salivary progesterone in first-price auctions. No such correlations are observed for salivary testosterone, estradiol, or cortisol. 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.

Finally, there are 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 does not increase trustworthiness. They also show that oxytocin

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 increases offers in an ultimatum bargaining game unless they believed that they received testosterone. Zethraeus et al. (2009) did not find a correlation between randomly administered testosterone and risk-taking in 200 healthy post-menopausal women. Behavioral experiments using placebo-controlled administration of hormones are important for establishing causal relationships. However, since endogenous hormones may affect behavior differently than administered hormones, they do not eliminate the need for correlation studies.

The paper is organized as follows: Section 2 outlines the experimental design. The results are reported in Section 3, where we also present some robustness checks. We provide an evolutionary explanation of our results, a comparison between our design and results and that by Chen, Katuščák, and Ozdenoren (2012), and further discussions in Section 4. The Appendix contains the instructions, screen shots, and the questionnaire. A Stata dataset and do-file that reproduces the entire analysis reported here and additional analysis is available from `http://www.econ.ucdavis.edu/faculty/schipper/`.

2 Experimental Design

The purpose of the experiments is to correlate bidding behavior in first-price auctions with data on the menstrual cycle for women. Every session of the experiment had three relevant phases: instructions, bidding, and a questionnaire.

Instructions: At the beginning of each session, subjects were randomly assigned to a computer terminal. Each of them received printed instructions (see appendix). 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). 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.

Bidding: Subjects repeatedly played a two-bidder first-price sealed-bid auctions with symmetric independent private values drawn from a piecewise linear distribution function constructed 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 $\{1, 2, ..., 100\}$. The respective

densities, l and h, are given by[3]

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

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

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 loosing 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 for screenshots.)

Questionnaire: At the end of the session, subjects completed a questionnaire on demographic information and the menstrual cycle (see appendix).

At the end of every session, we also collected a measure of the digit ratio (2D:4D), which is analyzed in detail in a companion paper, Pearson and Schipper (2012). Here we use 2D:4D only as a control in one of our specifications as a robustness check. Details are relegated to Section 3.2.

The experiment was conducted in two waves, the first one in the fall of 2007 and the second one in the winter of 2010. Latter sample differs from the first as we also collected salivary testosterone, estradiol, progesterone, and cortisol (at the beginning and at the end of the experiment), a behavioral risk measure using a Holt-Laury task for gains and losses before the auction task, and additional demographic information. The detailed analysis of those additional measures of the 2010 sample is presented in two companion papers, Schipper (2012a, b).

[3]The main reason for choosing this process of drawing values (as opposed to a uniform distribution) is to be able to replicate Chen, Katuščák, and Ozdenoren (2012). 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 distributions (see Chen, Katuščák, and Ozdenoren, 2007). Finally, the process makes simple proportional mark-down bidding heuristics less prominent.

Table 1: Demographics

Variable		Number	Mean	Std. Dev.
Subjects		400		
Female		187	0.47	
Age			20.43	2.64
Number of siblings			1.57	1.32
White	Male	86	0.22	
	Female	48	0.12	
	Total	134	0.34	
Asian	Male	105	0.26	
	Female	123	0.31	
	Total	228	0.57	
Hispanic	Male	17	0.04	
	Female	11	0.03	
	Total	28	0.07	
Black	Male	5	0.01	
	Female	3	0.01	
	Total	8	0.02	
Others	Male	9	0.02	
	Female	14	0.04	
	Total	23	0.06	
Math		20	0.05	
All Sciences		132	0.33	
Economics		181	0.45	
Other Social Sciences		114	0.29	
Humanities		28	0.11	

3 Results

Table 1 presents the demographics of our data.[4] We had 400 subjects in sessions of 8 subjects each. The first wave of experiments in 2007 had 24 sessions, while the second wave in 2010 had 26 sessions. Out of the 400 subjects, 187 are female. Most of our subjects are Asian-Americans (57%) followed by Whites (34%).[5]

[4]Subjects were allowed to select multiple majors and ethnic backgrounds. Thus, the means do not add up to unity.

[5]For comparison, the distribution of ethnicities among all UC Davis students is 42% White, 38% Asian, 3% Black, 14% Hispanic, and 3% Others. See http://facts.ucdavis.edu/student headcountethnicity.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. We advertised mostly by announcements in big classes accessible to us, on Facebook, and through the distribution of leaflets. The experiment was advertised as a "market game" and Orsee by Greiner (2004) was used as recruitment system.

From all 187 female subjects we obtained information about their menstrual cycle and administration of hormonal contraceptives. Table 2 presents the distribution across menstrual cycle phases. The definition of 28-days standardized menstrual cycle phases (third and fourth columns) is identical to the definition of menstrual phases in Chen, Katuščák, and Ozdenoren (2012). It assumes that all women follow a menstrual cycle standardized to 28 days. We distinguish the menstrual phase (days 1 to 5), the follicular phase (days 6 to 13), the peri-ovulatory phase (days 14 to 15), the luteal phase (days 16 to 23), and the premenstrual phase (days 24 to 28). Women who take hormonal contraceptives do not have a natural menstrual cycle, and their circulating levels of hormones may differ from naturally cycling women.[6] Therefore we consider for the classification of women into menstrual cycle phases only women who *do not* take hormonal contraceptives, so called *naturally cycling* women. Roughly 19% of women in our sample administer hormonal contraceptives. This number is reasonable given the relative young age of women and their ethnic background.[7] We classified women taking hormonal contraceptives further into women who are likely to take currently the active ingredient of the hormonal contraceptive and women who are currently on their "pill break" or a placebo (i.e., inactive ingredients only); see page 13 for a detailed discussion. One woman reported that she is pregnant. Since pregnant women do not experience a natural menstrual cycle, we exclude her from our analysis. For comparison, we report in the last column of Table 2 the expected frequency of natural menstrual cycle phases assuming a uniform probability to participate in the experiment at any day of a 28 days standard menstrual cycle conditional on 19% of the female population taking hormonal contraceptives. The remaining columns 5 to 8 report distributions on alternative specifications of menstrual cycle phases that will be discussed later in Section 3.1.

For our analysis, we fix three features. First, to control for correlation 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). Since we have 400 subjects in sessions of eight subjects, we have 50 clusters and thus 50 independent observations.

Second, in the multivariate regression analysis, 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".

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[6]See Briggs and Briggs (1972), Kjeld et al. (1976), Wiegratz et al. (1995), Coenen et al. (1996), Spona et al. (1996), Kirschbaum, et al. (1999), Schultheiss et al. (2003), Edwards and O'Neal (2009), and Liening et al. (2010).

[7]The United States Department of Health and Human Services (2010) estimates that in the US roughly over 11% of Asian, Hispanic, and Black women between 15 to 44 years of age use the pill compared to over 21% of White women. The use of the pill varies also with age. In the age group 15 to 19, it is slightly over 15%, while it increases to 26% in the age group 20 to 24. Note that almost half of our sample, 91 out of 187 women, are 19 or 20 years old.

Table 2: Menstrual Cycle Phases and Contraceptives

Menstrual Cycle Phases	Days	28-Days Stand. Number	28-Days Stand. Mean	Uniform Adj. Number	Uniform Adj. Mean	Fol. Phase Adj. Number	Fol. Phase Adj. Mean	Expected Frequency
Menstrual Phase	Days 1 - 5	33	0.18	32	0.17	33	0.18	0.15
Follicular Phase	Days 6 - 13	24	0.13	29	0.16	29	0.16	0.23
Peri-Ovulatory Phase	Days 14 - 15	14	0.08	13	0.07	10	0.05	0.06
Luteal Phase	Days 16 - 23	44	0.24	44	0.24	45	0.25	0.23
Pre-Menstrual Phase	Days 24 - 28	36	0.19	30	0.16	31	0.17	0.15
Total		151	0.81	148	0.81	148	0.81	0.81

Hormonal Contraceptives	Number	Mean	Expected Frequency
Active Ingredient	24	0.13	0.13
Placebo/Break	11	0.06	0.06
Total	35	0.19	0.19

Third, each specification of regressions on bids also includes a cubic polynomial in the value[8] and a set of period indicators to control for learning.[9] Each specification on total profits also includes the mean, the standard deviation, and the skewness of the subject's empirical distribution of values. All specifications also include an indicator for the 2010 sample. This indicator is not significant in our regression analysis below and dropping it changes the estimates and standard errors only slightly. 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 second authors website. As robustness checks, we will also consider specifications in which we will drop subsets of demographic variables or add session fixed effects.

We estimate versions of the following parametric model for bids:

$$b_{i,t} = \beta_0 + \beta_1 v_{i,t} + \beta_2 v_{i,t}^2 + \beta_3 v_{i,t}^3 + \delta_t p_t + \nu n_i + \zeta X_i + \rho M_i + \sigma C_i + \varepsilon_{i,t}, \tag{1}$$

where $b_{i,t}$ is the bid of subject i at time period $t = 1, ..., 30$, β_0 is a constant, $v_{i,t}$ is the value of subject i at time period t, n_i is a dummy that is one if i is in the 2010

[8]We 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). Moreover, it makes our specifications comparable to the ones employed in earlier versions of Chen, Katuščák, and Ozdenoren (2012). 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.

[9]Our 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.

sample, 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, M_i is a set of indicators for the menstrual phases of subject i, and C_i is a vector of two dummies for the use of hormonal contraceptives by subject i; one dummy for currently taking active ingredients of the hormonal contraceptive and one dummy that is one if subject i is currently in the "pill break" or on the placebo. $\varepsilon_{i,t}$ is the unobserved error term of subject i in period t (clustered at the session level). Whenever we include dummies for the menstrual phases, we force the coefficient for the gender dummy to zero for all subjects.

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 independent variables.

Specifications bids1 and profits1 in Table 3 show that there are substantial gender differences in terms of bids and total profits respectively. On average, women bid 2.2 points higher and earn \$3.60 less than men when controlling for demographics and major of study. This is substantial since the average total profit earned in the auctions is \$14.43 (standard deviation 7.82, minimum \$-7.38, maximum \$38.85).[10] It amounts to about 25% of average profit. This observation is qualitatively robust to dropping any of the control variables. The result is consistent with Chen, Katuščák, and Ozdenoren (2012) as well as with earlier results by Casari, Ham, and Kagel (2007) and Ham and Kagel (2006).

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

Specifications bids2 and profits2 in Table 3 include dummies for the menstrual cycle phases of naturally cycling women (assuming a 28-day standardized menstrual cycle) as well as the dummies for women taking hormonal contraceptives. Recall that since women on hormonal contraceptives do not have a menstrual cycle, we do not classify them into menstrual cycle phases. We observe that naturally-cycling women bid significantly higher than men except in the follicular and the peri-ovulatory phases. For instance, women in the premenstrual phase bid about 2.1 points higher than white men. The luteal phase is only marginally significant ($p = 0.091$). Similarly, women earn significantly lower profits than men in all phases of the menstrual cycle except in the peri-ovulatory phase. For instance, women in the luteal and premenstrual phase earn more than \$3.50 less than White men. The midcycle is the time in the menstrual cycle when fecundity peaks (see Wilcox et al., 2001). We interpret this finding in Section 4.

Note that our analysis involves multiple testing. Since we consider five menstrual cycle phases, there is a relatively large chance that we find a "significant" correlation

[10]This amount excludes the \$5.00 show-up fee for every subject and any other earnings from the lottery task in the 2010 sample (see Schipper, 2012a, b). Because of these other earnings, no subject left with negative pay. Average total payoff was \$18.81 with a minimum of \$5.00 and a maximum of \$41.23 in the 2007 wave and \$19.03, \$5.00 and \$48.38 respectively in the 2010 wave. The experiment lasted on average 50 and 80 minutes for the 2007 and 2010 waves, respectively.

Table 3: Estimated Effects on Bids and Profits using 28 Days Standardized Menstrual Cycle Phases

	(bids1)	(bids2)	(profits1)	(profits2)
Age	−0.1064	−0.1046	0.1939	0.1940
	(0.0831)	(0.0872)	(0.1511)	(0.1561)
Num. of Siblings	0.2065	0.2273	−0.4002	−0.4343
	(0.1614)	(0.1647)	(0.2615)	(0.2623)
Asian	−0.9559*	−0.8129*	0.8046	0.5901
	(0.4782)	(0.4532)	(0.7077)	(0.7045)
Other	−0.5672	−0.5178	0.0313	−0.0393
	(0.8526)	(0.8620)	(1.3341)	(1.3505)
Mathematics	−1.6078	−1.5705	2.7789**	2.7510*
	(1.0735)	(1.0869)	(1.2977)	(1.3732)
Science & Engineering	0.0812	0.0449	1.4346	1.5189
	(0.6458)	(0.6850)	(0.9420)	(0.9774)
Economics	0.3486	0.4539	0.9101	0.8435
	(0.6394)	(0.6336)	(0.9976)	(0.9526)
Social Science	0.7172	0.6177	−0.4270	−0.3354
	(0.6335)	(0.6661)	(0.9878)	(1.0452)
Humanities	0.0223	0.1036	0.0216	0.0153
	(0.5769)	(0.5841)	(1.0024)	(1.0168)
Female	2.1962***		−3.5981***	
	(0.5109)		(0.7463)	
Menstrual Phase		2.0296***		−2.9256**
		(0.7424)		(1.2044)
Follicular Phase		1.7390		−2.6952**
		(1.0592)		(1.2059)
Peri-ovular Phase		1.7862		−2.3565
		(1.1144)		(1.6630)
Luteal Phase		1.5212*		−3.5390***
		(0.8827)		(1.2741)
Premenstrual Phase		2.1271***		−3.6121***
		(0.7517)		(1.2497)
Active Ingredient		4.3124***		−5.7247***
		(1.1725)		(1.9541)
Placebo/Break		2.7912**		−4.7719**
		(1.2844)		(1.9542)
Number of Observations	11970	11970	399	399
R^2	0.8508	0.8515	0.2612	0.2682

Standard errors (clustered at the session level) in parentheses. Significance levels: *10%; ** 5%; *** 1%. We omit to report coefficients for the cubic polynomial in value and period indicators (bids1 and bids2), the mean, standard deviation, and skewness of the empirical distribution of values (profits1 and profits2) as well as the dummy for the 2010 sample.

between bidding or profits and some menstrual cycle phases even though there is no true correlation (i.e., a false positive). To account for multiple testing, we apply the conservative Bonferroni correction. If the desired significance level for a menstrual cycle phase is 5%, the Bonferroni corrected significance level for each phase should be 1% (since there are five phases). Our observations with respect to bids are robust to Bonferroni

correction. For profits, the menstrual phase is just marginally significant when Bonferroni corrected ($p = 0.019$ before Bonferroni correction), while the follicular phase is insignificant when Bonferroni corrected ($p = 0.030$ before Bonferroni correction). Latter does not affect our main conclusion. Our observations are also robust if we control for session fixed effects. They are also qualitatively robust to dropping controls for ethnicities, age, or siblings. However, the peri-ovulatory phase becomes marginally significant for bids and profits ($p = 0.088$ and $p = 0.089$ for bids and profits, respectively, before Bonferroni correction) if we drop controls for major of study. This is not surprising as the menstrual cycle dummies and the dummy for the use of hormonal contraceptives jointly control for gender and females select on average into different majors than males. For instance, in the 2010 sample all of our five math majors are male and 68% of our econ majors are male.

Observation 2 (Menstrual Cycle) *Naturally cycling females bid significantly higher and earn significantly lower profits than men except during the midcycle.*

We also collected information on hormonal contraceptives that may influence behavior. 22 out of 35 women using hormonal contraceptives provided us with the exact names of the contraceptives 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 (i.e., placebo) for one week during which a withdrawal bleeding usually occurs (e.g. Avian, Desogen, Junel, Microgestin, Ortho-Tri-Cyclen, Sprintec, and Yasmin). Then there are oral contraceptives that contain the active ingredient for 24 days after which an inert ingredient is taken for 4 days during which withdrawal bleeding usually occurs (e.g. Yaz). Finally, there are extended cycle oral contraceptives that contain an active ingredient for 84 days after which an inert ingredient is used for 7 days during which withdrawal bleeding usually occurs (e.g. Seasonale). Except for Depo Provera, all hormonal contraceptives reported involve a regular break/placebo during which circulating levels of progesterone are expected to be lower than when active ingredients are taken. This break may affect behavior. Not all women may observe the break but skip the placebo or break in order to avoid any withdrawal bleeding. Given the information in our sample we were able to classify 11 women as likely being in the break or taking the placebo. We assume that women who are stating to use oral contraceptives containing active ingredients over 24 days and whose withdrawal bleeding started within

the last 4 days can be classified as being in the break or taking the placebo. For women on other hormonal contraceptives, we assume that women stating that their withdrawal bleeding started within the last 7 days can be classified as being in the break or taking the placebo. This classification is presented in the regressions with two dummies, "Active Ingredient" and "Placebo/Break", respectively.

All hormonal contraceptives contain some form of progestin, a synthetic version of progesterone, as an active ingredient. 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).[11] 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). Moreover, hormonal contraceptives also seem to affect circulating levels of testosterone. Alexander et al. (1990) report that users of oral contraceptives exhibit higher blood plasma concentrations of testosterone. But Wiegratz et al. (1995) and Coenen et al. (1996) report that women on certain hormonal contraceptives have lower levels of plasma testosterone, and a similar finding was reported by Schultheiss et al. (2003) for salivary testosterone and estradiol. Testosterone is thought to be positively associated with aggression although no consistent correlation has been reported for women (Dabbs and Hargrove, 1997). Testosterone has been shown to be positively correlated with risk-taking in men in the gain domain (Apicella et al., 2008, Schipper, 2012b) but Schipper (2012b) also shows for the 2010 subsample of this study that no such correlation is present in women. As previously mentioned, higher risk-taking is correlated with lower bids in our first-price auctions. To sum up, hormonal contraceptives may have differing effects on bidding behavior although the progesterone-GABA-A connection seems most compelling. We observe in Table 3 that women who are classified as taking the active ingredient of the hormonal contraceptive bid significantly higher and earn significantly lower profits than men. The difference in average profits amounts to a substantial 40%. Women who are classified as being in the "pill break" or taking the placebo/inactive ingredient of the hormonal contraceptives also bid higher and earn less profits than men. The coefficients are smaller than the coefficients for women on the active ingredient but the difference between the coefficients is not significant. The observations remain qualitatively unchanged if we control for session fixed effects or drop controls for demographics.

Observation 3 (Hormonal Contraceptives) *Females on hormonal contraceptives bid significantly higher and earn significantly lower profits than men. The coefficients for women who currently take the active ingredient of the hormonal contraceptive are larger than for women on the placebo/break but the differences are not significant.*

We believe that this finding is consistent with the progesterone-GABA-A connection,

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

but we cannot claim a causal effect since it may be due to a selection effect. In particular, women who decide to take hormonal 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. 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.

3.1 Robustness to Menstrual Phases Specifications

One major implicit assumption behind specifications bids2 and profits2 reported in Table 3 is that all women have a *menstrual cycle duration of 28 days*. However, we find substantial variation in usual cycle length. Out of 152 naturally cycling women, 150 reported their usual cycle length. The average is 29.6 days with a standard deviation of 3.7.[12] One woman reported that her usual cycle length is 32 days, her first day of her last menstrual cycle was 160 days away, and that she is not pregnant and is not using any hormonal contraceptives. Because of this abnormal cycle or report, we drop her in the following regression analysis. Further noise may be due to intrapersonal variability in cycle length. The length of the menstrual cycle may vary from cycle to cycle even within the same woman, and the woman can never know the exact length of her *current* menstrual cycle. Finally, there is measurement error due to imperfect recall. Self-reports may be inaccurate and this inaccuracy may depend on the day of the menstrual cycle. Menstruating women usually know that they are menstruating while later in the cycle women may not remember exactly their first day of their menstrual cycle. This raises the question whether or not our results are robust to slight changes in the definitions of the menstrual phases.

We can use the collected information on the usual length of the menstrual cycle to construct more individualized menstrual cycles. *Individualized phases* are constructed in two ways: uniformly adjusted phases and follicular adjusted phases.

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

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

We define the female subject i to be in the

1. *Uniformly Adjusted Menstrual Phase* if and only if $x_i \leq \frac{5.5}{28}$,

[12]Regarding the "Length Menstrual Cycle", answers of "$>$ 35 days" have been normalized to 37 days. Answers "$<$ 25 days" have been normalized to 24 days. Our estimations are robust to small changes of those upper and lower bounds.

2. *Uniformly Adjusted Follicular Phase* if and only if $\frac{5.5}{28} < x_i \leq \frac{13.5}{28}$,

3. *Uniformly Adjusted Peri-ovulatory Phase* if and only if $\frac{13.5}{28} < x_i \leq \frac{16.5}{28}$,

4. *Uniformly Adjusted Luteal Phase* if and only if $\frac{16.5}{28} < x_i \leq \frac{23.5}{28}$,

5. *Uniformly Adjusted Premenstrual Phase* if and only if $\frac{23.5}{28} < x_i$.

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

1. *Follicular Adjusted Premenstrual Phase* if and only if $y_i > d_i - 5$,

2. *Follicular Adjusted Luteal Phase* if and only if $y_i > d_i - 13$ and i is not in the Follicular Adjusted Premenstrual Phase,

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

Next, female subject i is in the

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

Finally, female subject i is in the

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

Table 2, columns 5 to 8, show empirical distribution of uniformly adjusted and follicular adjusted menstrual cycle phases in our female sample. The distributions differ only slightly. Note that we are able to define the uniformly and follicular adjusted phases only for women who reported to us their typical cycle length.

Our results remain robust when using uniformly or follicular adjusted phases as controls. In fact, the differences between the coefficients of menstrual cycle phases become more pronounced. The regression specifications in Table 4 are analogous to specifications bids2 and profits2 in Table 3 except that we replaced the 28 day standardized phases by uniformly adjusted phases (specifications bids3 and profits3) and follicular adjusted phases (specifications bids4 and profits4), respectively. Again, we find that females bid

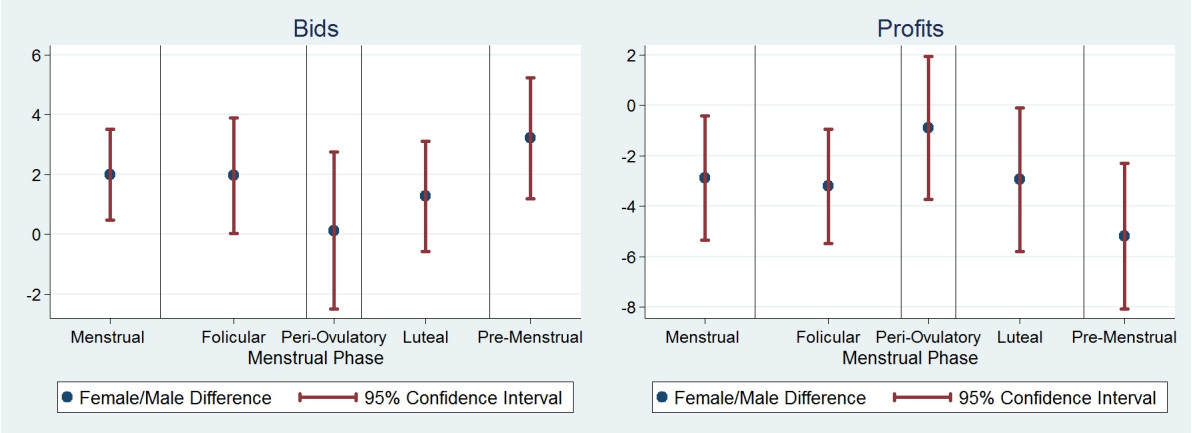
Table 4: Estimated Effects on Bids and Profits using Alternative Specifications of the Menstrual Cycle Phases

	(bids3)	(profits3)	(bids4)	(profits4)
Age	−0.1014	0.1820	−0.1022	0.1840
	(0.0885)	(0.1577)	(0.0895)	(0.1594)
Num. of Siblings	0.2130	−0.3914	0.2311	−0.4074
	(0.1641)	(0.2602)	(0.1621)	(0.2615)
Asian	−0.7696*	0.5445	−0.7846*	0.5819
	(0.4472)	(0.7043)	(0.4484)	(0.7013)
Other	−0.4822	−0.1002	−0.5209	−0.0303
	(0.8496)	(1.3387)	(0.8581)	(1.3285)
Mathematics	−1.4975	2.6804*	−1.5796	2.6900*
	(1.0679)	(1.4011)	(1.0643)	(1.4018)
Science & Engineering	0.1048	1.4062	0.0538	1.4404
	(0.6680)	(0.9699)	(0.6913)	(0.9723)
Economics	0.4435	0.8553	0.4575	0.8178
	(0.6113)	(0.9153)	(0.6217)	(0.9254)
Social Science	0.7699	−0.5188	0.6533	−0.4043
	(0.6381)	(1.0278)	(0.6672)	(1.0340)
Humanities	0.1251	−0.0698	0.0791	−0.0524
	(0.5610)	(0.9979)	(0.5800)	(1.0079)
Uni. Adj. Menstrual Phase	2.0180**	−2.9035**		
	(0.7586)	(1.2331)		
Uni. Adj. Follicular Phase	1.9924**	−3.2285***		
	(0.9636)	(1.1341)		
Uni. Adj. Peri-ovular Phase	0.1726	−0.9243		
	(1.3080)	(1.3984)		
Uni. Adj. Luteal Phase	1.2902	−2.9541**		
	(0.9086)	(1.4104)		
Uni. Adj. Premenstrual Phase	3.2272***	−5.1993***		
	(0.9953)	(1.4311)		
Fol. Adj. Menstrual Phase			2.0229***	−2.9191**
			(0.7411)	(1.2007)
Fol. Adj. Follicular Phase			1.6868*	−3.3845***
			(0.9662)	(1.0915)
Fol. Adj. Peri-ovular Phase			1.1966	−1.3865
			(1.3331)	(1.5906)
Fol. Adj. Luteal Phase			1.4775	−2.8421*
			(0.9580)	(1.4882)
Fol. Adj. Premenstrual Phase			2.7755***	−4.8858***
			(0.9794)	(1.3642)
Active Ingredient	4.2583***	−5.6819***	4.3040***	−5.7320***
	(1.1797)	(1.9575)	(1.1784)	(1.9640)
Placebo/Break	2.7850**	−4.7452**	2.7988**	−4.7502**
	(1.2850)	(1.9415)	(1.2889)	(1.9517)
Number of Observations	11880	396	11880	396
R^2	0.8522	0.2788	0.8518	0.2765

Standard errors (clustered at the session level) in parentheses. Significance levels: *10%; ** 5%; *** 1%. We omit to report coefficients for the cubic polynomial in value and period indicators (bids3 and bids4), the mean, standard deviation, and skewness of the empirical distribution of values (profits3 and profits4) as well as the dummy for the 2010 sample.

significantly higher and earn significantly lower profits than white males in all phases except during the midcycle. These findings are qualitatively robust to controlling for session fixed effects or dropping demographic controls (incl. controls for major of study). When we account for multiple testing using Bonferroni correction in specification bids3, then the uniformly adjusted menstrual phase remains marginally significant while the premenstrual phase is significantly higher. For specification profits3, the uniformly adjusted follicular and premenstrual phases remain significant after Bonferroni correction. Turning to follicular adjusted phases, in specification bids4 both the follicular adjusted menstrual and premenstrual phases are still significant after Bonferroni correction. For profits in specification profits4, the follicular premenstrual phase remains marginally significant while the follicular and premenstrual phases are significant after Bonferroni correction.

Figure 2: Men-Women Differences of Bids and Profits



As an example, Figure 2 illustrates the male-female differences of bids and profits respectively across various phases of the uniformly adjusted menstrual cycle.

We should point out that our statistical observations with regard to the menstrual cycle depend crucially on men as baseline. Only the coefficients of the peri-ovulatory and premenstrual phases of the uniformly adjusted menstrual cycle (specifications bids3 and profits3) are significantly different from each other at the 5% level. We believe that a larger sample size of women would allow for more precise estimates.

3.2 Further Observations and Robustness Checks

Closer inspection of Tables 3 reveals that Asians bid lower than white males although the differences are small and only marginally significant. This may be interpreted as Asians taking higher risks. It does not necessarily translate into significantly higher profits though. Moreover, it is not robust to controlling for menstrual cycle phases using our

alternative definitions (see Table 4).

We also observe in Tables 3 and 4 that mathematics majors earn significantly more profits. The difference is not small, translating into 17% of average profits, although it is only marginally significant in Table 4. Exactly 5% of our participants in the experiment reported to major in mathematics. That bidding may vary with majors is known in the literature. For instance, Casari, Ham, and Kagel (2007) report more aggressive bidding of economics and business majors in common value auctions.

Bidding above your valuation is a weakly dominated action in first-price auctions with symmetric independent private values. Nevertheless, we observe such bids especially in the first rounds and especially by women. From 12,000 bids, 357 bids or roughly 3% were made above valuation. Of these inadmissible bids, 263 or about 74% were made by women and 325 or 91% occurred in the first 15 bidding rounds. Could it be that our results are driven by gender differences in those inadmissible bids? To answer this question, we rerun specifications analogous to bids2 to bids4 but drop all bids above valuation. The magnitudes of most coefficients of interest are slightly reduced in size except for the peri-ovulatory phase dummy in the specification analogous to bids2, which is slightly increased and marginally significant ($p = 0.079$). But no such effect is observed for specifications analogous to bids3 and bids4 using individualized menstrual cycle phases. We report in Table 5, bids5, the specification analogous to bids3 for the uniformly adjusted phases with inadmissible bids being dropped. We conclude that because most of the "overbids" are submitted by women, some of the menstrual cycle effects we observe are due to overbidding but the main finding obtains even when bids above valuation are dropped and menstrual cycle phase dummies are carefully defined. Interestingly, the coefficient for women on the active ingredient of the hormonal contraceptive is reduced remarkably. Since progestin is the main active ingredient, this finding is consistent with Schipper (2012b) who finds that higher bidding is positively correlated with salivary progesterone and that this correlation disappears when excluding bidders who bid weakly dominated bids.

Random matching between bidding rounds minimizes repeated games effects. Moreover, we control for some learning effects by inclusion of a set of dummies for the rounds. However, the correlation between bidding behavior and menstrual cycle phases in later rounds may differ from earlier rounds. We test this by interacting the menstrual cycle phase dummies and the dummies for the use of hormonal contraceptives with a dummy for the first 15 rounds and add them to specifications analogous to bids2 to bids4. The coefficients for the menstrual cycle phase dummy then indicate the correlation between bidding behavior and the respective menstrual cycle phase in the *last 15 rounds* when the dummy indicating the first 15 rounds is zero (and analogous for the dummies indicating the use of hormonal contraceptives). In Table 5, bids6, is analogous to specification bids3 for uniformly adjusted phases. Our results remain qualitatively unchanged. We believe that the correlations we find are not just due to behavior of relatively inexperienced bidders in the first 15 rounds. We like to point out though that the coefficient for women on the active ingredient of the hormonal contraceptive is somewhat reduced. From specification

Table 5: Further Observations and Controls: Exclusion of inadmissible bids, the effect of last 15 periods, PMS, and, the digit ratio

	(bids5)	(bids6)	(bids7)	(bids8)
Uni. Adj. Menstrual Phase	1.7502**	2.1988**	2.2697***	1.9292**
	(0.7602)	(0.9604)	(0.7614)	(0.7770)
Uni. Adj. Follicular Phase	1.9994**	2.0735*	2.1076**	1.8979*
	(0.9925)	(1.0492)	(0.9733)	(0.9699)
Uni. Adj. Peri-ovular Phase	0.2147	0.3767	0.5017	0.1374
	(1.4688)	(1.1982)	(1.3302)	(1.3280)
Uni. Adj. Luteal Phase	0.9991	1.3941	1.5059	1.2078
	(0.8531)	(0.9336)	(0.9191)	(0.9223)
Uni. Adj. Premenstrual Phase	2.3997**	3.6017***	3.3508***	3.1494***
	(0.9066)	(0.9941)	(1.0060)	(0.9928)
Active Ingredient	2.9538***	3.6596***	4.5184***	4.1678***
	(1.0526)	(1.1738)	(1.1672)	(1.1749)
Placebo/Break	3.0233**	3.1437**	2.8858**	2.7465**
	(1.2631)	(1.3718)	(1.2208)	(1.2648)
Menst. Ph. x Periods 15-30		−0.3617		
		(0.8995)		
Foll. Ph. x Periods 15-30		−0.1625		
		(0.4165)		
P.-ovul. Ph. x Periods 15-30		−0.4080		
		(0.7071)		
Lut. Ph. x Periods 15-30		−0.2079		
		(0.6041)		
Premens. Ph. x Periods 15-30		−0.7492		
		(0.8664)		
Act. Ingred. x Periods 15-30		1.1975		
		(0.9888)		
Placebo/Break x Periods 15-30		−0.7170		
		(0.6117)		
Currently PMS			−1.0805	
			(0.8708)	
Digit Ratio				6.3958
				(7.7127)
Number of Observations	11523	11880	11880	11880
R^2	0.8792	0.8522	0.8523	0.8522

Standard errors (clustered at the session level) in parentheses. Significance levels: *10%; ** 5%; *** 1%.
We suppress from the report coefficients for age, num. of siblings, asian, other, mathematics, science & engin., economics, social science, humanities, the dummy for the 2010 sample as well as the cubic polynomial in value and period indicators.

bids5 we know that those women are also more likely to submit weakly dominated bids. Thus, they have the highest opportunity to learn and thus they may learn on average to reduce their bids more than others.

Could our results with respect to menstrual cycle phases be simply due to noise in our data? That is, how often would we arrive falsely at a similar conclusion when we randomly assign women to either menstrual cycle phase or the use hormonal contraceptives? To study this question, we created a set of dummy variables, one for each menstrual cycle phase and one for the use of hormonal contraceptives. Instead letting the dummy variable be one for women in the respective menstrual cycle phase (or women who use hormonal contraceptives), we randomly let dummies be one for women but require that the resulting distribution of phases and hormonal contraceptives is identical to the distribution for uniformly adjusted phases (see Table 2). Coefficients for those dummies are estimated in specifications analogous to bids3 and profits3. We repeat this procedure for 1000 times and count for the bid specification (profit specification, respectively) how often the coefficient for the random menstrual phase is significantly positive (negative, respectively) *and* the coefficient for the random peri-ovulatory phase is insignificant or significantly negative (positive, respectively). Out of this 1000 repetitions, we obtain 28 false positives for bids and 33 false positives for profits. We conclude that our results are unlikely to be due to noise.

We also collected information on whether women in our sample were currently experiencing symptoms of pre-menstrual syndrome (PMS). PMS refers to physical and psychological discomfort in the 5 to 11 days before menstruation (see Yonkers et al. 2008). When we control for currently experiencing symptoms of PMS with a dummy variable in specifications analogous to bids2 to bids4 as well as profits2 to profits4, then the coefficient is not significant. In Table 5, bids7 is a specification analogous to bids3. We should mention that upon further investigation we are unsure whether all women in our sample fully understood what is meant by PMS. For example 9 out of 35 women who reported to currently experience PMS are also in the menstrual phase. They may confuse PMS with dysmenorrhea or menstrual pain like menstrual cramps. We suggest that future studies collecting information on PMS should make sure that subjects have a clear understanding of the meaning of the pre-menstrual syndrome. Note that Chen, Katuščák, and Ozdenoren (2012) also do not find a significant effect of PMS.

While menstrual cycle information is a proxy for current hormones, we are also interested in what sense hormone exposure in utero could shape bidding behavior. We use as a proxy the ratio between the length of the 2nd (index) finger and the 4th (ring) finger of the subjects' right hand (so called "digit ratio" or 2D:4D). 2D:4D is believed to be positively correlated with prenatal exposure to estrogen and negatively correlated to prenatal exposure to testosterone (Manning et al., 1998, Lutchmaya et al., 2004, Hönekopp et al., 2007). At the end of the experiment we scanned the right hand of subjects with a conventional office image scanner. The second and fourth digits were later measured independently by both authors 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 authors 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. In a companion paper, Pearson and Schipper (2012), we present the methodology, hypothesis, and the analysis in detail showing essentially a null finding with respect to the digit ratio. Here we just consider the inclusion of the digit ratio as a robustness check for our previous findings. When the digit ratio is included as a regressor in specifications analogous to bids2 to bids4 and profits2 to profits4, the results remain almost unchanged although the magnitudes of the coefficients are slightly lower. This may be explained with the fact that there is a sexual dimorphism with respect to the digit ratio. Females have on average a larger digit ratio than men. Thus, the digit ratio encodes some information of being female, i.e., the information of all variables pertaining to the menstrual cycle phases and hormonal contraceptives. As an example, we report in Table 5, bids8, a specification analogous to bids3 but controlling for the digit ratio.

In the 2010 wave of the experiment, we also run a lottery choice experiments both for gains and losses, collected salivary testosterone, estradiol, progesterone, and cortisol, and further information such as dietary preferences, smoking, sexual behavior etc. Since these measures require a careful exposition and pertain to just 26 out 50 sessions analyzed here, we refer for the analysis to two companion papers, Schipper (2012a, b).

4 Discussion

4.1 An Evolutionary Hypothesis

Our main finding is that women bid as if they are more risk averse than men except during the midcycle when fecundity is highest. This suggests an evolutionary explanation: relatively more risky bidding of women may be correlated with generally more risky behavior of women during their fecund period. Risky behavior may lead to a higher probability of conception, genetic diversity, and higher quality offspring through extrapair mating. This may be especially successful in monogamous societies with a 50:50 sex ratio where some females must be matched with substandard males. Thus females with risky behavior near ovulation may have a higher reproductive success. On one hand, extrapair mating is risky because if discovered it is punished severely in most societies and may lead to a loss of the long term mating partner who supports child rearing. There is some evidence for greater mate guarding near ovulation (see Gangestad, Thorndill, and Garver, 2002, and Haselton and Gangestad, 2006), which may be the long-term mate's best response to riskier behavior of the female during her fecund window and may in turn require more risky behavior of females to escape the guard. On the other hand, men of higher genetic quality tend to have poorer parental qualities (Gangestad and Simpson, 2000). To maximize the quality of the genetic endowment, a woman should have the highest propensity to extrapair mating during their fecund period. There is some empirical evidence for this hypothesis in the literature. Baker and Bellis (1990)

claim that the frequency of extra-pair mating is higher during the fecund phase of the menstrual cycle. Bressan and Stranieri (2008) show that partnered women favor single men with more masculine features during their fecund phase, while they prefer attached men during their phase with low fecundity. Jones et al. (2005) find that women report lower commitment to their relationship partner in phases of the menstrual cycle when fecundity is high.[13] Wilcox et al. (2004) show that the frequency of intercourse increases during the fecund period.[14]

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

In the empirical literature, the evidence for cyclic changes in risk preferences of women is mixed. Using a subsample of the current study and the Holt-Laury lottery task to measure risk preferences, Schipper (2012a) finds no evidence for changes in risk preferences across the menstrual cycle. Yet, a prominent sequence of papers starting with dissertations by Rogel (1976) and Morgan (1981) suggest that women are more likely to avoid the risk of being raped near ovulation.[15] Chavanne and Gallup (1998) and Bröder and Hohmann (2003) claim based on evidence gathered with questionnaires on daily activities that women unconsciously engage in less risk taking around the most fecund phase of the menstrual cycle.[16] Fessler (2003) argues that rape is not less frequent during the ovulatory phase. In a very recent study, Guéguen (2012) shows that women seek a larger distance to a shady male confederate in a waiting room during the most fecund phase of the menstrual cycle, where fecundity is measured with a LH test. It is conceivable that risk preferences of women may differ by "sexual" loss and gain domains analogous to differences in risk preferences in gain and loss domains of monetary lotteries à la Kahneman and Tversky (1979). Women may avoid the risk of being raped during ovulation but at the same time

[13]For related evidence, see Gangestad, Thornhill, and Garver-Apgar (2006), Penton-Voak et al. (1999), and Penton-Voak and Perrett (2000).

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

[15]We were unable to obtain copies of the dissertations.

[16]Bröder and Hohmann (2003) is an improved replication study of Chavanne and Gallup (1998). Yet, according to private communication by Arndt Bröder the authors were not able to replicate later their own results in Bröder and Hohmann (2003).

they may be more receptive to extra-pair mating with a mate of *their choice*. Indeed, Guéguen (2009a) shows with a field experiment that young women are more likely to provide their phone numbers when approached by an attractive male confederate in the most fecund phase of their menstrual cycle. Similarly, Guéguen (2009b) shows with a field experiment in a night club that young women are more likely to accept an invitation to a slow dance from an attractive male confederate in the most fecund phase of their menstrual cycle.[17] Finally, women may unconsciously exert more self-control during the fecund phase of the menstrual cycle to counter changes in risk preferences. This may mask any consistent observability of changes in risk preferences over the menstrual cycle and contribute to the mixed evidence in the literature.[18]

4.2 Comparison to Chen, Katuščák, and Ozdenoren (2012)

We used the same auction program as Chen, Katuščák, and Ozdenoren (2012). We are extremely grateful to Yan Chen for providing us the program. This program runs on z-tree (Fischbacher, 2007). The differences between our treatment and the treatments of Chen, Katuščák, and Ozdenoren (2012) are follows: First, Chen, Katuščák, and Ozdenoren (2012) have treatments with known distributions of values and treatments with unknown distributions. Our treatment is identical to their treatment with known distributions in order to eliminate as many confounding factors as possible.[19] Second, Chen, Katuščák, and Ozdenoren (2012) collect information on the use of hormonal contraceptives only for women in half of their data set (Data 2) while we collect this information for all women in our sample. Results on menstrual cycle effects may be sensitive to this information as women on hormonal contraceptives do not experience a natural menstrual cycle. Different from Chen, Katuščák, and Ozdenoren (2012), we do not classify women who use hormonal contraceptives into menstrual cycle phases since women on hormonal contraceptives do not experience a menstrual cycle. Third, while both Chen, Katuščák, and Ozdenoren (2012) and we rely on self-reported information on the menstrual cycle and hormonal contraceptives, the former use a prospective measure by asking female subjects "How many days away is your next cycle?" while we use a retrospective measure by asking "How many days ago was the first day of your last menstrual period?" The reason is that we think it is easier for subjects to remember than to remember *and* predict. We also collect for females in our sample further information on the average length of the menstrual cycle and its regularity, which allows us to construct individualized menstrual cycle phases instead assuming a standardized 28-day menstrual cycle for each women in

[17]For related evidence on consumption of appearance-enhancing goods during the fecund phase and changes in dress preferences across the menstrual cycle, see Saad and Stenstrom (2012) and Durante et al. (2008) as well as Haselton et al. (2007), respectively.

[18]We would like to thank an anonymous referee for suggesting this explanation.

[19]Treatments with unknown distributions were included by Chen, Katuščák, and Ozdenoren (2012) in order to study ambiguity in auctions, which was subsequently reported in Chen, Katuščák, and Ozdenoren (2007)

our sample. Menstrual cycle lengths can vary substantially between women and results on menstrual cycle effects may be sensitive to such variations.

Our sample differs in demographics from Chen, Katuščák, and Ozdenoren (2012) as we have a larger share of Asians/Asian Americans and a lower share of Whites. Differences in the ethnic composition of the sample may matter. For instance, Harlow et al. (1997) show differences in between-subject standard deviation of cycle length and the odds of having cycles longer than 45 days in African-American and European-American young postmenarcheal women.

Any of above mentioned differences may contribute to the different conclusions drawn in Chen, Katuščák, and Ozdenoren (2012) and our study. Their finding that the sine-shaped pattern of bidding over the menstrual cycle in their data is driven by women on hormonal contraceptives is consistent with our finding that women on the active ingredient of the hormonal contraceptive bid somewhat higher than women on the placebo/break.

4.3 Conclusion

We present a replication study of Chen, Katuščák, and Ozdenoren (2012). We also find that women bid significantly higher than men and earn significantly lower profits than men in first-price auctions with symmetric independent private values. However, while Chen, Katuščák, and Ozdenoren (2012) report that women bid higher than men in *all* phases of their menstrual cycle, we find that naturally cycling women bid significantly higher than men and earn significantly lower profits than men except in the midcycle when fecundity is highest. We suggest an evolutionary explanation whereby risky behavior during the fecund window increases the probability of conception, the quality of offspring, and genetic variety. Chen, Katuščák, and Ozdenoren (2012) report that womens' bids throughout their cycle follow a sine-like curve that reaches the maximum in the follicular phase and the minimum in the luteal phase, and that this sine-like curve is entirely driven by hormonal contraceptives. We report that women on hormonal contraceptives bid significantly higher and earn substantially lower profits than men. Moreover, women on the active ingredient of the hormonal contraceptive bid somewhat higher than women in on the placebo/break.

Several differences in the designs could account for the differences. We focus on the case of known value distributions while Chen, Katuščák, and Ozdenoren (2012) also have sessions with unknown distributions. We collect information on the use of hormonal contraceptives for all women in our sample whereas Chen, Katuščák, and Ozdenoren (2012) collect this information just for a subsample. We also collect additional information on the cycle for all women so that we are not forced to assume a 28 day standardized menstrual cycle but allow for individual differences in the cycle length. Moreover, our methodology for collecting self-reported measures of the menstrual cycle information differs slightly. The ethnic compositions of both samples differ as well. Finally, in the analysis we control for women on hormonal contraceptives separately from naturally cycling women because former do not experience the same hormonal changes associated

with the menstrual cycle.

Since self-reported menstrual cycle information lacks accuracy with regard to the underlying changes of hormones such as estradiol, progesterone, follicle-stimulating hormone (FSH) and the luteinizing hormone (LH), it would be preferable to measure these hormones directly. Schipper (2012a) presents such a follow-up study in which he collects salivary testosterone, estradiol, progesterone, and cortisol. He find that bidding is significantly positively correlated and profits are significantly negatively correlated with progesterone. No other correlations with salivary hormones are observed. His observation is consistent with our findings in this paper. Progesterone figures prominently in the menstrual cycle increasing after ovulation, peaking in the luteal phase and decreasing before menstruation (see Figure 1). We observe that women in the premenstrual phase bid significantly higher and earn significantly lower profits than white men. Yet, we also observe that women in the menstrual phase bid significantly higher and earn significantly lower profits than white men. Thus, we suspect that not just salivary steroids such as progesterone could affect bidding and profits in auctions but also FSH and LH who peak during the midcycle. Those hormones cannot be measured in saliva.

That hormones may influence economic behavior is relevant for several reasons: First, one can ask which hormones are related to which preferences. While such a relationship does not add to economic explanations, it may allow us to constrain the set of preferences we find relevant to study in particular economic contexts. Moreover, a tight biological explanation may allow us to explain the evolution of preferences in particular economic contexts. With the current design we cannot disentangle attitudes such as risk aversion, ambiguity aversion, anticipated looser regret, joy of winning, overconfidence, relative payoff concerns etc. and further studies are needed to get a precise understanding between hormones and preferences. Schipper (2012b) studies the correlation between risk aversion using a Holt-Laury lottery task and salivary steroids. He finds that testosterone is positively correlated with risk-taking in men but not in women, and that in women risk-taking is negatively correlated with cortisol. These observations apply only to risk-taking in the gain domain. In the loss domain, no significant correlations between risk-taking and salivary testosterone, estradiol, progesterone, and cortisol are observed. Interestingly, progesterone does not play a role for choice under risk but Schipper (2012a) shows that it is correlated with bidding and profits in first-price auctions. Thus, we may speculate that differences in behavior of women and men in first-price auctions are not driven by risk aversion in the narrow sense, and that hormones affecting behavior in choice under risk may differ from hormones affecting competitive behavior in first-price auctions.

A Instructions

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:

  Your Payoff = Your Value - Your Bid;

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

  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:

  Your Payoff = Your Value - Your Bid;

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

  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:

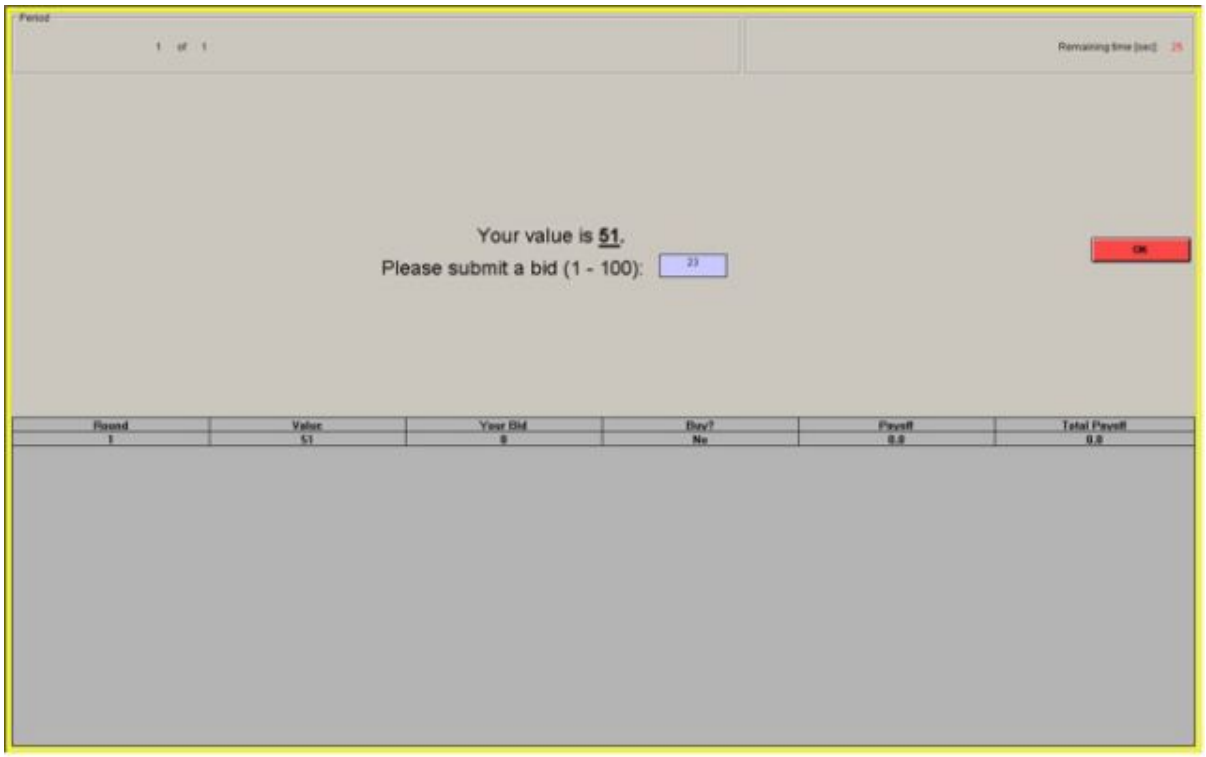
   If a bidder's value is 25, it must have been drawn from the low distribution.

   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.

B Screen Shots



C Questionnaire

POST-EXPERIMENT SURVEY Terminal No.: ___

We are interested in whether there is a correlation between participants bidding behavior and some socio-psychological factors. The following information will be very helpful for our research. This information will be strictly confidential.

1. What is your gender?

☐ Male ☐ Female

2. What is your ethnic origin?

☐ White ☐ Asian/Asian American ☐ African American ☐ Hispanic ☐ Native American ☐ Other

3. What is your age? ___

4. How many siblings do you have? ___

5. Would you describe your personality as (please choose one)

☐ optimistic ☐ pessimistic ☐ neither

6. 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

7. What is your major field of study?

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

8. For female participants only:

- How many days ago was the first day of your last menstrual period? ___
- On average, how many days are there between your menstrual cycles?
  ☐ < 25 ☐ 25 ☐ 26 ☐ 27 ☐ 28 ☐ 29 ☐ 30 ☐ 31 ☐ 32 ☐ 33 ☐ 34 ☐ 35 ☐ > 35
- How many days does your menstruation last on average?
  ☐ 2 ☐ 3 ☐ 4 ☐ 5
- 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. If yes, what type? _____ ☐ I do not remember.
- Do you currently experience any symptoms of PMS? (please choose one) ☐none ☐mild ☐severe

In the 2010 wave of the experiment, we collect additional demographic information on sexual behavior, lifestyle, dietary preferences etc. not used in this study. Some of this information is used in Schipper (2012a, b).

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