Why Can't a Woman Bid More Like a Man?*

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Abstract

We find robust gender difference in bidding behavior in sealed bid auctions with independent and private valuations in a laboratory setting. In particular, we find that women bid significantly higher and earn significantly less than men do in the first-price auction, while we find no evidence of a gender difference in the likelihood of dominant strategy play in the second-price auction. At a biological level, in the first-price auction, women during menstruation, when the estrogen level is lowest, do not bid differently from men. The gender difference in the first-price auction is driven by women during other phases of the menstrual cycle when they have higher estrogen levels.

Keywords: gender, menstrual cycle, auction
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1 Introduction

The gender gap in income and social positions has been a persistent phenomenon in the U.S. labor market. For example, in 1999, women's earnings were 76 percent of men's earnings (U.S. Department of Labor 1999). Observable factors, such as education, job experience, hours of work, and so on, explain no more than 50 percent of the wage gap. Proposed reasons for the remainder of this gap range from economic discrimination to gender differences in decision-making (Goldin 1990).

Gender differences in decision-making have long fascinated economists, psychologists and other social scientists. In a recent survey, Croson and Gneezy (2004) synthesize studies of preference differences between men and women in laboratory and field experiments in economics and psychology, focusing on risk taking, social preferences and reaction to competition. Their synthesis of this research indicates that, on average, women are more risk averse than men, with a few caveats and exceptions. Furthermore, various studies find that women's preferences for competitive situations are lower than men (e.g., Gneezy, Niederle and Rustichini (2003); Niederle and Vesterlund (2004); Gneezy and Rustichini (2004)).

These experimental results are consistent with findings from survey data. For example, Jianakoplos and Bernasek (1998) examine household holdings of risky assets to determine whether there are gender differences in financial risk taking. They find that, as wealth increases, the proportion of wealth held in risky assets increases by a smaller amount for single women than for single men. They further find that gender differences in financial risk taking are correlated with race, age and the number of children. In a related study, Hersch (1996) examines data from a large national survey, and finds substantial differences by gender and race in risky behavior such as smoking, seat belt use, preventive dental care, exercise and blood pressure monitoring. Overall, Hersch finds that women make safer choices than men, and whites make safer choices than blacks.

While both experimental and survey results show robust gender differences in various decision making tasks, we are not aware of any study in economics which investigates potential biological sources underlying this gender difference. To address this possibility, we examine the gender difference in the first- and second-price auctions. In addition, we investigate the effects of the menstrual cycle on women's bidding behavior.

The menstrual cycle is "one of the very few biological processes that exhibit a virtually complete dimorphism between male and female members of the human species" (Nyborg 1983). Most women between the ages of 15 and 50 are regularly affected by the hormonal and physiological changes that are associated with the cyclical process of ovulation and menstruation (Richardson 1992). This is an age interval when many important life-changing decisions are made. Thus, whether these hormonal and physiological changes affect women's risk preferences, attitudes towards competition, or cognitive performance, is an important yet open question.

Menstrual cycle research in medicine and psychology has found that most menstruating women tend to "experience a variety of physical, psychological and behavioral changes during the period between ovulation and menstruation" (Richardson 1992). In simple cognitive tasks, Hampson and Kimura (1992) find that women perform better on certain male-oriented tasks (e.g., spatial ability) during menstruation, when estrogen is at its lowest level, than during other phases of their cycle. Conversely, women perform better on certain female-oriented tasks (e.g., articulatory speed and accuracy) during periods of high estrogen levels. One implication of these findings is that any gender gap should be smallest during menstruation, and larger during other phases of the menstrual cycle. Researchers have also studied the effects of the cycle on visual information processing, memory, mood, etc. None of the tasks, however, concerns economic decision making.

One study that explores potential biological effects on economic performance is a paper by Yuan, Zheng and Zhu (forthcoming) that investigates the relationship between lunar phases and stock market returns of 48 countries. They find that stock returns are lower on the days around a full moon than on the days around a new moon. The magnitude of the return difference is three to five percent per annum. Furthermore, the lunar effect is independent of other calendar-related anomalies. Citing biological evidence for lunar effects on human body and behavior, the authors note that the most common monthly cycle is menstruation, which is about the same length as the lunar cycle. Although the authors do not directly measure the effect of the menstrual cycle on investment behavior, it is well known that there is a synchronous relationship between the menstrual cycle and the lunar phases (Law 1986).

If the menstrual cycle and respective hormone levels can explain a significant part of the gender difference, we might be able to reduce the gender gap by adjusting policies. If, for example, the menstrual cycle affect women's willingness to take risks, it might be beneficial for them to know how their risk preference systematically varies during the cycle, in order to time key decisions during certain phases of the cycle. This might lead to better decisions in investments, negotiations and other competitive situations, which could improve their earnings and social positions. If the menstrual cycle affects women's cognitive performance, important exams, such as the Scholastic Aptitude Test in the United States, the General Certificate of Education in the United Kingdom, and the National College Entrance Examination in many other countries should be scheduled multiple times during the exam month, so women can choose when to take the exam based on their cycle.[1] Better exam scores can lead to better colleges, which in turn, can lead to better earning potentials.

In this paper, we examine gender differences in competitive situations by conducting laboratory experiments in the first- and second-price sealed-bid auctions with independent and private valuations. In the first-price auction, the Bayesian Nash equilibrium is sensitive to a bidder's risk preference, while in the second-price auction, bidding one's true value is a weakly dominant strategy regardless of a bidder's risk preferences. Therefore, the first-price auction involves a greater degree of strategic thinking than does the second-price auction. However, determining the dominant strategy in a second-price auction is not a trivial task in itself. Indeed, many previous experiments show that a significant proportion of bidders overbid in second-price auctions (e.g., Chen, Katuscak and Ozdenoren (2002)). Thus, these two auctions provide two different competitive situations in which to study gender differences in decision-making. Our results show different effects for the two auction mechanisms. In the first-price auction, we find that women bid significantly higher than do men. However, in the second-price auction, the proportion of dominant strategy play is not significantly different between men and women. These results are consistent with the explanation that risk attitude is the driving force behind the gender gap in competitive bidding in the first-price auction. We find no evidence of a gender effect in the likelihood of dominant strategy play, indicating that the ability to recognize and play the dominant strategy does not vary across genders.

To investigate potential biological causes of this gender gap, we investigate whether hormonal variations during the menstrual cycle cause women's behavior to change systematically during different menstrual phases. We find that, in the first-price auction, during menstruation, when estrogen levels are lowest, women do not bid differently from men. Thus, the gender difference in the first-price auction is driven primarily by women during other phases of the menstrual cycle, when they have higher levels of estrogen. This result supports the Hampson-Kimura hypothesis (1992). We find that the gender difference is statistically insignificant during menstruation, when estrogen levels are lowest. Meanwhile, women bid significantly higher during other phases of the menstrual cycle, when they have higher estrogen levels.

In addition to gender and menstrual cycle, we also examine the impact of other demographic characteristics, such as the number of siblings, race and age. We find that participants with more siblings bid significantly less in the first-price auction. However, the number of siblings has no significant effect on bidding behavior in the second-price auction. This finding is consistent with findings from the psychology literature on sibling relationships and social, emotional and cognitive development. For example, Bryant (1989) finds that sibling caretaking adds significantly to the prediction of social perspective taking, empathy, attitudes towards competition, and locus of control. Relevant to our finding in the first-price auction, having more siblings is correlated with a child's increased preference for competitive situations. In the first-

[1] Partly based on the widespread popular belief in the notion of paramenstrual cognitive debilitation, it is not uncommon for female high school graduates in Beijing to receive luteinizing hormone shots before the National College Entrance Exam to shift their menstrual cycle.

price auction, this could translate into more risk-taking behavior. Using a large data set from the National Longitudinal Survey of Youth, Rodgers, Harrington, van den Oord and Rowe (2000) conclude that there is no direct causal link found between family size and children's intelligence. Our result on the lack of an effect of sibling number in the second-price auction is consistent with this finding.

Using demographics without controlling for educational background might lead to the omitted variable bias due to the correlation between demographic characteristics and educational background and the impact of educational background on bidding.[2] To address this concern, we repeat the analysis controlling for subjects' educational background. To do so, we construct a vector of the number of college classes in five different categories: Mathematics and Statistics, Science and Engineering, Economics and Business, Other Social Science, and Humanities and Other courses. All our results for the demographic and menstrual cycle variables are robust to this set of control variables.

We are aware of two other papers which examine the effects of demographics in auctions. Rutstrom (1998) presents an experimental study of the English, Vickrey and the Becker, DeGroot and Marschak (1964) mechanisms, using home-grown values.[3] In her study, participants bid on a box of gourmet chocolate truffles. Bidder values for the truffles are home-grown and assumed to be private. The demographic variables include gender, race, marital status, graduate status, age, and annual income. Rutström finds that, pooling across all auctions, whites submit lower bids on average, and females exhibit more variance in bidding behavior than males. As bidder values are not induced, the causes of these gender and race effects remain unknown.

Casari, Ham and Kagel (2004) explore demographic and ability effects in common value auctions, using the induced-value method. The demographic and ability variables include gender, SAT and ACT scores, major, and class standing (freshman, sophomore, etc.). They find that women inexperienced in common value auction experiments bid higher and thus suffer more from the winner's curse than do men, while women experienced at such auctions do at least as well as men. They also find that inexperienced subjects with lower SAT/ACT scores, as well as business and economics majors, are more likely to overbid and bankrupt. However, they do not investigate the biological causes for the gender difference. We will compare these results with our results in more detail in Section 3.

Our paper presents the first study in economics on how the menstrual cycle affects economic decision-making. We provide a biological explanation for the observed gender difference in the first-price auction. The medical and psychology literature on menstrual cycles and cognition has never examined the domain of auctions or other competitive tasks. Thus, this paper contributes to the general literature on menstrual cycle and cognition by opening up a new and important domain. Results in this new domain can potentially impact economic policies. Furthermore, it contributes to the auction literature by introducing a comprehensive list of demographic and education variables and demonstrating their systematic effects on bidding behavior. From the perspectives of auction theory and design, these findings are important for at least two reasons. First, many real-world auctions combine bidders of vastly different demographic and educational backgrounds. One prominent example is auctions on the Internet. The online auction technology allows geographic dispersion of bidders and asynchronous bidding. These conveniences make it easier to obtain a relatively large and heterogeneous group of bidders. Therefore, it is important to investigate the systematic effects of various dimensions of heterogeneity. Second, if observable characteristics of bidders lead to predictable differences in bidding behavior, then the auctioneer may choose the most appropriate auction mechanism depending on the particular group of bidders.

The rest of the paper is organized as follows. Section 2 presents the experimental design and post-experiment survey. Section 3 presents our main results. Section 4 concludes the paper.

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[2]For example, women might be less likely to take economics or engineering courses. Meanwhile, participants with a background in economics or engineering might be better at the strategic analysis of the auction game and therefore bid systematically differently.

[3]Home-grown values refer to the subjective values participants have formed for a good, in the absence of any values induced by the experimenter. It is often used in field experiments.

2 Experimental Design

In this section, we summarize the main features of the design and the post-experiment questionnaire.

2.1 Economic Environments and Experimental Procedure

We use a full factorial ($2 \times 2 \times 2$) design. The first four treatments consist of the first-price auction with known and unknown distributions and the second-price auction with known and unknown distributions. In these treatments, each session consists of eight bidders randomly re-matched into groups of two each round. In the other four treatments, each session consists of eight bidders and four auctioneers, each of whom is randomly re-matched into a group of three each round, with each group consisting of one auctioneer and two bidders. Since risk attitude is important in bidding in the first-price auction, while the likelihood of playing the dominant strategy in the second-price auction depends on the ability to figure out the dominant strategy, comparison of behavior in the first- and second-price auctions allows us to study gender differences in situations with varying strategic complexity.[4]

[Table 1 about here.]

Table 1 summarizes the relevant features of the experimental sessions, including information conditions, number of subjects per session, auction mechanisms, exchange rates and the total number of subjects in each of the eight treatments. For each treatment, we conducted five independent sessions using networked computers at the Research Center for Group Dynamics Laboratory at the University of Michigan. This design gives us a total of forty independent sessions and four hundred subjects, recruited from an email list of Michigan undergraduate and graduate students, which excludes graduate students in Economics.

In our experiments, bidder valuations are known to be independent draws from either the low value distribution $F^1(\cdot)$ or the high value distribution $F^2(\cdot)$. In the experiment, the support set of these distributions is given by $\{1, 2, \cdots, 100\}$, and the respective densities, f^1 and f^2, are given by

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

In all treatments, we set the probability that bidder value is drawn from $F^1(\cdot)$ as $\delta = 0.70$. We announce this probability in treatments without ambiguity, but do not provide any information about it in treatments with ambiguity.

At the beginning of each session, subjects randomly drew a PC terminal number. Then, each subject was seated in front of the corresponding terminal, and given printed instructions. After the instructions were read aloud, the subjects completed a set of Review Questions, to test their understanding of the instructions. The experimenter then checked their responses and answered questions. The instruction period varied between fifteen to thirty minutes, depending on the treatment. In the eight-subject sessions, all eight subjects were seated in the same room. In the twelve-subject sessions, the four auctioneers went to an adjacent lab after the instruction period while the bidders remained in the original lab. In the treatments with ambiguity, the auctioneers were privately informed of the value of δ on their screens at the beginning of each round. Each round consisted of the following stages:

1. In each of the twelve-subject treatments, each auctioneer set a reserve price, which could be any integer between 1 and 100, inclusive.

[4] In a companion paper, we study the second dimension (known vs. unknown distributions) and the third dimension (eight- vs. twelve-subject).

2. Meanwhile, for treatments with an unknown distribution only, each bidder estimated the chance that the valuation of the *other* bidder in the group was drawn from the high value distribution, i.e., an estimate of $1 - \delta$.

3. Next, each bidder was informed of the reserve price of his auctioneer (in the twelve-subject treatments) and his own valuation. In the eight-subject treatments, the reserve price was implicitly set to zero. Then each bidder simultaneously and independently submitted a bid, which could be any integer between 1 and 100, inclusive. Bidders were instructed that, if they did not want to buy, they could submit any positive integer below the reserve price.

4. Bids were then collected in each group and the object was allocated according to the rules of the auction.

5. After each auction, each bidder received the following feedback on his screen: his valuation, his bid, the reserve price, the winning bid, whether he received the object and his payoff.

   Each auctioneer received the following feedback: whether the object was sold, his reserve price, the bids in his group and his payoff.

In each treatment, each session lasted thirty rounds with no practice rounds. At the end of thirty rounds, all participants completed a questionnaire to elicit demographic information (Appendix B).

The experiments were conducted from October 2001 to January 2002. Each session lasted from forty minutes to an hour. The exchange rates are presented in Table 1. The average earning was $18.78 per subject. Instructions are included in Appendix A. The data are available from the authors upon request.

2.2 Demographics, Menstrual Cycle and Educational Background Variables

To study the impact of demographics, menstrual cycle and educational background on competitive bidding behavior, we obtain demographic and menstrual cycle information from our subjects by using a survey at the end of the experiment. The survey is included in Appendix B.

In the survey, we elicit the following information: gender, race, age, number of siblings, self-described personality and self-described emotions during the experiment. For female participants, we also elicit the number of days until the next menstrual cycle, as well as the presence of premenstrual syndrome (PMS). Menstrual cycle information is elicited to identify hormone levels that may account for a biological basis for gender differences in competitive environments. In this paper, we report the effects of objective measures of demographics, therefore, we do not include variables on self-described personality or emotions (Questions 5 and 6 in the survey[5]). Since the PMS variable is not statistically significant in any of our results, we exclude it from the analysis presented here.

When using regression analysis to evaluate the impact of the elicited demographic and biological characteristics on bidding, the interpretation of the results might be contaminated by the omitted variable bias due to the fact that (omitted) educational background might also affect bidding behavior, and this background might be correlated with some of the demographic variables. For example, subjects who have taken more courses in science and engineering or economics and business might be better at analytical reasoning, and hence bid differently. At the same time, men might be more likely to have taken these classes than women. To address this issue, we first obtained a list of courses each subject had completed from the Registrar Office at the University of Michigan. We categorize these courses into five mutually exclusive categories: Mathematics and Statistics, Science and Engineering, Economics and Business, Other Social

[5]These two questions were included as our primary objective in our companion paper, Chen et al. (2002), was to study the ambiguity attitude. These personality information could be used to estimate the boundary for the set of priors in the α-MEU framework.

Sciences, and Humanities and Other.[6] In our analysis, we then measure the educational background by a vector that records the number of courses that the subject has taken in each of these five categories.

Due to the small number of auctioneers, we present only our bidder results. Analogous results for auctioneer behavior are available from the authors upon request. We have 320 bidders in our experiment. Among them, we obtained course information for 287 bidders. We are not able to match the remaining subjects based on their identifying information (name and social security number) with the records at the Registrar Office. Of the female bidders, five did not provide their menstrual cycle information. To avoid sample composition issues, we use only observations with a complete set of data. This criterion yields a sample size of 282 bidders. Summary statistics for our sample are presented in Table 2.

[Table 2 about here.]

Our variables of interest fall into three natural categories:

- Demographic variables (1)-(5): Of the 282 subjects, 149 are female. Of the six racial categories in the survey, we find that 54% of the participants are white, 33% are Asian/Asian American, and the remaining 13% are African American, Hispanic, Native American or Other. We group the latter into a combined "Other Ethnicities" category for under-represented minorities.

- Education variables (6)-(10): These variables record the number of courses a participant has taken in each category prior to the experiment.

- Menstrual phase variables (11)-(15): Using their answer to Question 7 in the survey, we categorize the female participants into one of five phases, based on a common definition of phases[7] for a normal 28-day menstrual cycle. Menstrual phases are characterized by varying levels of several hormones (e.g., Richardson (1992), Chapter 1).

  – Menstrual phase (days 1-5 of the cycle): If fertilization does not occur, secretion of estrogen and progesterone ceases, followed by degeneration and expulsion of the uterine lining. Women during this phase have the lowest levels of estrogen and progesterone.
  – Follicular phase (days 6-12): Follicle-stimulating hormone stimulates an ovarian follicle to develop and secrete estrogen. The increased level of estrogen causes reconstruction and proliferation of the uterine lining and stimulates the pituitary to produce the luteinizing hormone. Women during this phase have large amounts of circulating estrogen and very little progesterone.
  – Peri-ovulatory phase (days 13-15): The luteinizing hormone reaches its peak at mid-cycle, which causes the mature follicle to release the ovum through the wall of ovary. Under the influence of the luteinizing hormone, the original site of the ovum develops into a secretory organ known as the corpus luteum. During this phase, estrogen levels show a slight decrease.
  – Luteal phase (days 16-23): Estrogen and progesterone are secreted by the corpus luteum to prepare the uterine lining for implantation should fertilization occur. During this phase, estrogen levels reach a second peak.
  – Premenstrual phase (days 24-28): This phase is sometimes called the late luteal phase. Both estrogen and progesterone decline drastically during this phase.

[6] We categorize courses that we could not directly map to any of these categories (such as "Research") based on a subject's major. Similarly, we categorize a cross-listed course to an earlier category on our list. Finally, we use our own judgement to categorize a few of the remaining courses.

[7] An alternative coarser definition, for example, calls the first 15 days the follicular phase, and the second half the luteal phase.

Throughout the cycle, estrogen is at its lowest level during the menstrual phase, starts to increase during the follicular phase and reaches its first peak at the end of the follicular phase, decreases slightly during the peri-ovulatory phase, reaches its second peak during the luteal phase and starts to decrease during the premenstrual phase.

Of these three categories of variables used in our analysis, demographic information should be accurate, unless a participant has a particular reason to lie. Course information is also accurate, as they are obtained directly from the Registrar's Office. Menstrual cycle information, however, relies on a participant's estimate of the number of days until the next menstrual cycle, and therefore, might be subject to estimation or rounding error. The exception is for women in the menstrual phase, where we would expect accurate information. We also note that day count is not the most reliable method of defining menstrual phases, even though it is the most frequently used method in menstrual cycle studies (Sommer 1992). The most reliable method is direct assay of hormones, which requires invasive procedures such as blood collection. As Sommer (1992) notes, however, day count could be used as a legitimate indicator of hormone level if the sample size is large. Most medical and psychology studies use around 20 subjects, while we have 149 subjects. Thus, we believe our data on menstrual cycle is an appropriate indication of subject hormone levels.

[Table 3 about here.]

Table 3 presents the correlations for the demographic, education, and menstrual phase variables. This data yields several interesting correlations. For example, women are less likely to take science and engineering courses than are men. Asians/Asian Americans are more likely to take Mathematics and Statistics, and Economics and Business courses than other subjects. However, they are less likely to take Other Social Science courses, and Humanities and Other courses. These correlations underscore the importance of controlling for educational background when investigating the impact of demographics and menstrual cycle on bidding, to limit any omitted variable bias.

3 Results

In this section, we present our analysis of demographics, menstrual cycle and educational background on bidding behavior in the first- and second-price auctions.

We first point out some common features that apply throughout our analysis. First, for treatments with auctioneers, we use only observations for which the value is at least as great as the reserve price, since otherwise it is rational to bid anything below the reserve price without affecting the outcome of the auction. Second, in all the empirical models that we estimate, we adjust the standard errors for clustering at the session level. We do so because participants, due to their interaction within a session, might affect each other's behavior in a dynamic sense, and therefore observations on individual subjects within a session cannot be assumed to be independent. Third, we use a 5% statistical significance level (unless stated otherwise) to claim existence of any causal effects. Fourth, in interpreting the results of the multivariate analysis, the omitted category is white male.

Recall that, in a first-price independent private-value auction, more risk aversion leads to higher bids (Riley and Samuelson 1981). In Chen et al. (2002), we prove that a similar conclusion holds for ambiguity aversion. In that paper, we use a structural approach to estimate the bidding function. Since our emphasis here is on the impact of demographics, menstrual cycle and education, we adopt a simpler reduced form approach by using a polynomial approximation of the bidding function.

[Table 4 about here.]

Table 4 presents an OLS analysis of the impact of demographics, educational background, and menstrual cycle on bidding behavior in the first-price auction. In this analysis, the dependent variable is the Bid. The explanatory variables are the demographic, education, and menstrual cycle variables. Furthermore, each specification also includes a cubic polynomial in the value and reserve price as well as period indicator variables to control for learning.[8] In specification (1), we use only the demographic variables. To control for educational background, we add the education variables in specification (2). To understand the gender effect at the hormone level, we add the menstrual cycle variables in specification (3). All three categories are included in specification (4).[9]

We then perform a similar analysis for the second-price auction. Recall that, in the second-price auction, bidding one's true value is a weakly dominant strategy. This is true regardless of whether the distribution of other bidders' valuations is known or unknown. Therefore, neither risk nor ambiguity attitude affects the optimal bidding strategy in the second-price auction. In our sample, 38 percent of all bids equal their corresponding value (dominant strategy play), while 46 percent are above value (overbidding) and 16 percent are below value (underbidding).

[Table 5 about here.]

Table 5 presents a logit analysis of the impact of demographics, educational background, and menstrual cycle on the likelihood of playing the dominant strategy in the second-price auction. The dependent variable is an indicator variable for bidding one's true value, while the independent variables are the same as those in the analysis of the first-price auction.[10]

We now summarize the results in the first- and second-price auctions in the order of gender, menstrual cycle, number of siblings, race, and educational background.

Result 1 (Gender). *In the first-price auction, women bid significantly higher than men. However, in the second-price auction, the likelihood of dominant strategy play is not significantly different between men and women.*

Support. *In specifications (1) and (2) in Table 4, the coefficients for Female are positive and highly significant. In specifications (1) and (2) in Table 5, the coefficients for Female are not significant.* ∎

While we do not rule out other plausible explanations, our gender effect in the first-price auction is consistent with findings from many previous studies which conclude that women are more risk averse in decision-making contexts (see Croson and Gneezy (2004) for a survey). However, the absence of a gender effect in the second-price auction indicates that women's ability to figure out the dominant strategy is not significantly different from men's. Using similar OLS regressions with earnings as the dependent variable, we find that women earn significantly less than men in the first-price auction with or without the control of educational backgrounds ($p < 0.01$ in both cases). Therefore, the significant behavioral difference translates into a significant difference in earnings.

We further investigate the effects of learning on gender differences in the first-price auction by comparing behavior in the first and last 10 rounds. We find that the Female coefficients in rounds 1-10 and rounds 21-30 are not significantly different, indicating that learning does not seem to change the gender differences in bidding behavior in the first-price auction.

In a closely related study, Casari et al. (2004) find that, in common value auctions, women inexperienced at such auctions bid substantially higher than do men and thus suffer more from the winner's curse, while women experienced at such auctions do at least as well as men. Unlike our independent private value environment, where risk aversion unambiguously leads to higher bids, the theoretical prediction of more

[8]Estimates are not displayed but are available from the authors upon request.

[9]In addition to the specifications presented in Table 4, we estimate a specification that includes Age^2 along with Age as an additional regressor to capture age nonlinearities, and a specification that converts the Sibling variable into three indicator variables: 1 sibling, 2 siblings, 3 or more siblings (0 siblings being the omitted category) to capture non-linearities in the number of siblings. The results are qualitatively the same as those presented in Table 4.

[10]We have also estimated an analogous probit specification, results of which closely parallel those of the logit analysis.

risk aversion is ambiguous in their common value environment. Therefore, it is not clear whether their gender difference is due to risk or not.

Nevertheless, we take seriously the possibility that women tend to bid higher, regardless of auction institutions. In particular, this conjecture implies that women should be more likely to overbid than men in a second-price auction. To investigate the validity of this conjecture, we use a logit analysis to explore potential gender effects in the likelihood of overbidding in the second-price auction.[11]

[Table 6 about here.]

Table 6 reports the logit analysis on the effects of demographics, education, and menstrual cycle on the likelihood of overbidding. The dependent variable is an indicator variable for bidding above one's true value, while the independent variables are the same as those in Tables 4 and 5. The results in Table 6 indicate no gender difference in the likelihood of overbidding, as the coefficients for Female in specifications (1) and (2) are insignificant. This refutes the conjecture that women tend to bid higher regardless of auction institutions. We will summarize other results from Table 6 in each appropriate demographic and education category below.

To understand the gender effects in Result 1, we explore whether there are biological explanations for this result. We do so by using the menstrual cycle information from the survey.

[Figure 1 about here.]

Figure 1 presents the Female-Male bid difference in various menstrual phases in the first-price auction. In this analysis, bids are regressed on period dummies, a third-degree polynomial in value and reserve price, the female dummy, and a third-degree polynomial in days in the cycle. We note that the bid difference in the first-price auction varies across the menstrual phases. The menstrual and pre-menstrual phases have the lowest bid difference, while the difference reaches its peak in the follicular phase. This is confirmed by the following regression analysis.

In Tables 4, 5 and 6, we replace the Female variable with the five menstrual phase variables in specifications (3) and (4). Specification (3) does not include education variables, while specification (4) does. In both cases, the omitted category is Male. Therefore, the coefficient on each of the menstrual phase variables compares bids of women in that particular menstrual phase with men's bids. Our analysis reveals some interesting findings.

Result 2 (Menstrual Cycle). *In the first-price auction, there is no significant difference in bids between women in the menstrual phase and men. However, women in the follicular, peri-ovulatory, luteal and premenstrual phases bid significantly higher than do men. In the second-price auction, the likelihood of dominant strategy play is not significantly different between men and women in any of the menstrual phases.*

Support. *In specifications (3) and (4) in Table 4, the coefficients for the menstrual phase are insignificant* ($p = 0.14$ *in specification (3) and* $p = 0.17$ *in specification (4)), while the coefficients for the follicular, peri-ovulatory, and luteal phases are all positive and significant. The coefficient for the premenstrual phase is significant at the 5% level in specification (3) and 10% level in specification (4). In specifications (3) and (4) in Table 5, none of the coefficients for the menstrual phases is significant.* ∎

To our knowledge, this is the first result in the economics literature which examines the effect of the menstrual cycle on decision-making. During the menstrual phase, when the estrogen level is the lowest, women do not bid differently from men in either the first-price or second-price auction. The gender gap in the first-price auction is driven by women during the other phases of the menstrual cycle when they have higher estrogen levels. Furthermore, the menstrual phase coefficients are statistically different from zero

[11] We thank John Kagel for suggesting this analysis.

and from one another. In particular, women in the follicular phase bid significantly higher than those in the menstrual phase ($p = 0.039$ in specification (3) and $p = 0.032$ in (4)), peri-ovulatory phase ($p = 0.025$ in specification (3) and $p = 0.060$ in (4)), or the premenstrual phase ($p = 0.000$ in specifications (3) and (4)). The double peak of high bids in the follicular and luteal phases mirrors the double peak of estrogen levels.

Our results relate to findings in the medical and psychology literature on menstrual cycle and cognition that explores the relationship between hormone variations and cognition. The list of cognitive tasks in such studies includes “simple arithmetic, short-term memory, verbal skills, visual-spatial, rote speed tasks, motor coordination, frustration tolerance, flexibility, stress responsivity, creativity, dressing behavior, asymmetric hemispheric activity, facial preference, body image and interest in erotica” (Epting and Overman 1998). Sommer (1992) reviews 45 such studies. Epting and Overman (1998) summarize 62 such studies. Based on these summaries as well as our own reading of more recent studies, the findings seem to be task-specific. Among the many studies reporting consistent cognitive changes across menstrual phases, Komnenich (1974) reports a decline in verbal fluency in the post-ovulatory and menstrual phases. Wuttke, Arnold, Becker, Creutzfeldt, Langenstein and Tirsch (1976) find faster performance in simple arithmetic tasks during the luteal phase. Dye (1992) finds significant cycle-related fluctuation in visual information processing, with the best performance in the pre-menstrual phase. Hausmann, Slabbekoorn, Goozen, Cohen-Kettenis and Gunturkun (2000) find a significant cycle difference in spatial ability as tested by Mental Rotation Test, with high scores during the menstrual phase and low scores during the luteal phase. As estrogen levels are lowest during the menstrual phase and highest during the follicular, peri-ovulatory and luteal phases, such results lead to the hypothesis (Hampson and Kimura 1992) that women perform better on certain male-oriented tasks (e.g., spatial ability) during menstruation than during other phases in the menstrual cycle. Conversely, women perform better on certain female-oriented tasks (e.g., articulatory speed and accuracy) during periods of high estrogen levels (follicular, peri-ovulatory and luteal phases).

Result 2 provides some support for the Hampson-Kimura hypothesis, as we find that gender difference is statistically insignificant during the menstrual phase, when estrogen levels are lowest, but is statistically significant during all other menstrual cycle phases.

Finally, we note that specification (4) in Table 6, indicates no overall gender difference in the likelihood of overbidding in the second-price auction. However, when we separate women into five categories according to their menstrual phases, women in the luteal phase are significantly less likely to overbid compared to men.

In addition to gender, we examine the effects of other demographic variables. Among them, we find that age has no significant effect on bidding in either auction. By contrast, the number of siblings and subject race yield significant effects.

Result 3 (Number of Siblings). *Participants with more siblings bid significantly less in the first-price auction. However, in the second-price auction, the number of siblings has no significant effect on the likelihood of dominant strategy play.*

Support. *In each of the four specifications in Table 4, the coefficient for the Number of Siblings is negative and significant. In Table 5, however, none of the coefficients for the Number of Siblings is significant.* ∎

There are numerous studies in the psychology literature on how sibling relationships affect the long term cognitive, emotional and social development of both older and younger siblings. For example, using direct observations and interviews, Bryant (1989) finds that, among the six components of social-emotional functioning (empathy, social perspective taking, acceptance of individual differences, locus of control, attitudes toward competition and attitudes towards individualism), sibling caretaking adds significantly to the prediction of all six measures. Furthermore, longitudinal prediction is enhanced on four of the six measures, i.e., social perspective taking, empathy, attitudes towards competition, and locus of control. Relevant to our finding in the first-price auction, having more siblings is correlated with a child’s increased preference for competitive situations. In the first-price auction, this could translate into more risk taking behavior, or more strategic thinking.

The relationship between family size and intelligence has been the subject of much earlier research (Anastasi 1956). Using a large data set from the National Longitudinal Survey of Youth, Rodgers et al. (2000) find no direct causal link between family size and children's intelligence. Our result on the lack of an effect of sibling number in the second-price auction is consistent with this finding.

In an economic study of the effect of the number of siblings on behavior in the laboratory. Glaeser, Laibson, Scheinkman and Soutter (2000) find that, in trust games, only children are much less likely to return money when they are recipients, which can be interpreted as being less trustworthy.

In addition to effects of sibling number, we find effects of race in bidding behavior.

Result 4 (Race). *In the second-price auction, participants from Other Ethnicities are significantly less likely to play the dominant strategy compared to whites. Furthermore, Asian/Asian Americans are significantly more likely to overbid compared to whites.*

Support. *In each of the four specifications in Table 5, the coefficient for Other Ethnicities is negative and significant. In each of the specifications (2) to (4) in Table 6, the coefficient for Asian/Asian American is positive and significant.* ∎

Result 4 indicates that participants from Other Ethnicities are significantly less likely to play the dominant strategy, compared to whites. Furthermore, Asian/Asian Americans are significantly more likely to overbid, compared to whites. We are not aware of other studies which examine cognitive abilities across racial groups in competitive situations.[12] In addition to Result 4, we find that, in the first-price auction, Asian/Asian Americans bid less than do whites, which is significant at the 10% level (specification (2) - (4) in Table 4). This is consistent with Asians exhibiting greater risk tolerance than whites. Using survey responses from the Health and Retirement Study, Barsky, Juster, Kimball and Shapiro (1997) find that Asians are the most risk tolerant of all ethnic groups in their study.

Lastly, we examine the effect of educational background on bidding behavior. In specifications (2) and (4) in Table 6, the coefficients for Economics and Business Courses are negative and significant. This indicates that participants who have taken more economics and business courses are significantly less likely to overbid in the second-price auction.

While we examine the effects of economics and business *courses*, Casari et al. (2004) examine the effects of economics and business *majors*. They find that economics and business majors substantially overbid in common value auctions relative to other majors. They conclude that "these students have a mind set such that they are more concerned with 'winning' the auctions than with maximizing their total profits from bidding, or that they are by nature overly aggressive in business transactions." While it is plausible that there is a self-selection bias in economics and business majors, we find that taking more economics and business courses *per se* significantly reduces overbidding. One other plausible explanation is that private value auctions are covered in many intermediate level economics courses, while common value auctions are not. Therefore, students taking more economics and business courses might have learned not to overbid in the second-price auction in one of their courses.

In addition, we find that, in the first-price auction, participants who take more Science and Engineering courses, as well as those who take more Other Social Science courses bid weakly less. As shown in specification (2) in Table 4, the coefficients for Science and Engineering Courses as well as Other Social Science Courses are negative and weakly significant at the 10% level.

To summarize, we find systematic evidence that demographic characteristics and college education backgrounds significantly affect bidder behavior in the first- and second-price sealed bid auctions. In particular, we find that women bid significantly higher and earn significantly less than men in the first-price auction, while the likelihood of dominant strategy play in the second-price auction is not significantly different across men and women. At the biological level, we find that, during menstruation, when estrogen levels are lowest,

[12] There is related controversial literature on race and cognition, which mostly relies on IQ tests, e.g., Herrnstein and Murray (1994) and Jacoby and Glauberman (1995).

women do not bid differently from men. The gender difference in the first-price auction is driven by women during other phases of the menstrual cycle when they have higher estrogen levels.

4 Conclusions

Women's and men's average levels of general intelligence are the same, based on the best psychometric estimates (Jensen (1998), chapter 13). However, the minds of men and women are not identical. Sex hormones, most notably estrogen and androgen, cause the brains of boys and girls to diverge during development (Pinker (2002), chapter 18). Researchers in psychology and medicine have found that, when estrogen levels are high, women perform better at tasks at which they typically do better than men, such as verbal fluency tasks. However, when estrogen levels are low, women perform better at tasks at which men typically do better, such as spatial ability tasks. In this study, we investigate gender differences in competitive bidding situations and explore the extent to which sex hormonal variations can account for these differences.

To study this question, we use data from a first-price sealed-bid private value auction to evaluate the gender differences due to risk preferences, and data from a second-price sealed-bid auction to evaluate any difference in the abilities to recognize dominant strategies. In the first-price auction, we find that women bid significantly higher than do men. This is consistent with findings in other contexts that women exhibit more risk averse behavior. Furthermore, we find no gender difference in the likelihood of dominant strategy play in the second-price auction. This finding indicates that, in our environment, there is no gender difference in the ability to figure out the dominant strategy. In addition to the likelihood of dominant strategy play, in the second-price auction, we find no gender difference in the likelihood of overbidding.

Having observed a robust gender difference in the first-price auction, we explore whether hormone variations can explain this difference. In the first-price auction, we find no difference in bidding behavior between men and women who are in their menstrual phase, when the estrogen levels are lowest. However, we find a gender difference for women during other phases of the menstrual cycle, with higher estrogen levels. This result is consistent with the Hampson-Kimura hypothesis (1992), which implies that the gender gap should be smallest during menstruation, and largest during the follicular, peri-ovulatory and luteal phases of the menstrual cycle. We find that the gender difference is indeed statistically insignificant during menstruation. The largest gender gap we find in our study occurs during the follicular and luteal phases, which mirrors the double peaks of the estrogen levels during the cycle. To our knowledge, this is the first paper in the economics literature, which examines the gender difference in decision-making at the biological level.

Although it is beyond the scope of this paper, we speculate that gender differences on cognitive tasks should be smaller for women past menopause and men of similar age, as post-menopause estrogen levels are much lower. For the same reason, differences in the cognitive decisions of pre-pubescent girls and boys should be smaller. Consistent with the latter prediction, Harbaugh, Krause and Liday (2002) find that, in their laboratory dictator games, the heterogeneity in dictator proposal among younger, pre-pubescent children (second, fourth and fifth graders) is driven entirely by height, not by sex. However, for the older post-pubescent children (ninth and twelfth graders), it is driven more by sex than by height. However, in a related study, Gneezy and Rustichini (2004) find significant gender difference in competitiveness in elementary school children when they face a running task. They find that competition enhances the performance of boys but not girls. We speculate that children's attitudes towards physical tasks, such as running, might be influenced more by early childhood socialization experience than their attitudes towards cognitive tasks.[13]

In addition to gender, we examine whether other demographic as well as education background variables systematically affect bidding behavior. We find that participants with more siblings systematically bid lower in the first-price auction, while the number of siblings does not have any effect on the likelihood of dominant

[13] Using casual empiricism, we observe that children before school age rarely socialize by engaging in cognitive tasks (such as reading or solving puzzles) together. Furthermore, on playgrounds, little boys seem to be chasing each other much more often than little girls, which might contribute to different attitudes towards competition.

strategy play in the second-price auction. This finding is consistent with findings from social and cognitive psychology that having more siblings increases a person's preference for competitive situations (Bryant 1989), but has no direct effect on children's intelligence (Rodgers et al. 2000).

In our study, race has significant effects on bidding in the second-price auction. We find that participants from Other Ethnicities are significantly less likely to play the dominant strategy compared to whites. Furthermore, Asian/Asian Americans are more likely to overbid in the second-price auction. We do not have a good explanation for this finding, nor are we aware of any other studies which examines cognitive abilities across racial groups in competitive situations.

When controlling for educational backgrounds, we find that, in the second-price auction, participants who have taken more economics and business courses are significantly less likely to overbid. We speculate that this might be due to familiarity with the second-price sealed-bid private value auctions, which might have been covered in intermediate undergraduate courses.

To summarize, this paper presents systematic evidence that gender, race, the number of siblings, and educational background significantly affect bidder behavior in the first- and second-price sealed-bid auctions in a private value environment. Furthermore, we use, for the first time in economics, menstrual cycle information to provide a biological basis for the gender difference in behavior. We hope that this study will spur more interests in the biological foundations of gender difference in behavior in economics.

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APPENDIX A. INSTRUCTIONS

The complete instructions for the twelve-subject, first-price auction with known distribution treatment are shown here. Instructions for the twelve-subject, first-price auction with unknown distribution treatment are identical except that 30% is replaced by x% and bidders are asked to give an estimate of x. Instructions for the corresponding eight-subject treatments are identical to their twelve-subject counterparts except that the parts concerning auctioneers are deleted in the eight-subject treatments.

Instructions for the second-price auction are identical to the first-price auction instructions except for "The Rules of the Auction and Payoffs" section and the "Review Questions;" hence only these two parts are provided here.

Experiment Instructions – K1$_{12}$

Name________ PCLAB __ Total Payoff _____

Introduction

- You are about to participate in a decision process in which an 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 considerable amount 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.

Procedure

- You each have drawn a laminated slip, which corresponds to your PC terminal number. If the number on your slip is from PCLAB 2 to PCLAB 9, you will stay in this room and you will be a bidder for the entire experiment. If the number on your slip is from PCLAB 10 to PCLAB 13, you will go to Room 212 after the instruction, and you will be an auctioneer for the entire experiment.
- In each of 30 rounds, you will be *randomly* matched with two other participants into a group. Each group has an auctioneer and two bidders. You will not know the identities of the other participants in your group. Your payoff each round depends ONLY on the decisions made by you and the other two participants in your group.
- In each of 30 rounds, each bidder's **value** for the object will be randomly drawn from one of two 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 if 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 three 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:

  - Each auctioneer will set a minimum selling price, which can be any integer between 1 and 100, inclusive.
  - Bidders are informed of the minimum selling prices of their auctioneers, and then each bidder will simultaneously and independently submit a bid, which can be any integer between 1 and 100, inclusive. If you do not want to buy, you can submit any positive integer below the minimum selling price.
  - 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 minimum selling price, the winning bid, whether you got the object, and your payoff.

    Auctioneers will get the following feedback: whether you sold the object, your minimum selling price, the bids, and your payoff.

- The process continues.

Rules of the Auction and Payoffs

- **Bidders**: In each round,

  - if your bid is less than the minimum selling price, you don't get the object:
    Your Payoff = 0
  - if your bid is greater than or equal to the minimum selling price, and:
    * 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. Therefore,

- 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.

- **Auctioneers**: In each round, you will receive two bids from your group.
  - If both bids are less than your minimum selling price, the object is not sold, and :
    Your Payoff = 0;
  - if at least one bid is greater than or equal to your minimum selling price, you sell the object to the higher bidder and
    Your Payoff = the Higher Bid.
- For example, if the minimum selling price is 1, bidder A bids 25, and bidder B bids 55, since $55 > 1$ and $55 > 25$, bidder B gets the object. Bidder A's payoff = 0; bidder B's payoff = her value - 55; the auctioneer's payoff = 55.
- There will be 30 rounds. There will be no 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 all rounds.
- Bidders: the exchange rate is $1 for ____________ points.
- Auctioneers: the exchange rate is $1 for ____________ points.

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

Review Questions: you will have ten minutes to finish the review questions. Please raise your hand if you have any questions or if you finish the review questions. The experimenter will check each participant's answers individually. After ten 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. The minimum selling price is 30 and your bid is 25, your payoff = __.
6. True or false:
   (a) __If a bidder's value is 25, it must have been drawn from the low distribution.
   (b) __If a bidder's value is 60, it must have been drawn from the high distribution.

(c) __You will be playing with the same two participants for the entire experiment.

(d) __A bidder's payoff depends only on his/her own bid.

(e) __If you are an auctioneer and your minimum selling price is higher than both bids, your payoff will be zero.

Experiment Instructions – K2$_{12}$

. . . . . .

Rules of the Auction and Payoffs

- **Bidders**: In each round,
  - if your bid is less than the minimum selling price, you don't get the object:
    Your Payoff = 0
  - if your bid is greater than or equal to the minimum selling price, and:
    - if your bid is greater than the other bid, you get the object. The price you pay depends on the minimum selling price and the other bid:
      - if the other bid is greater than or equal to the minimum selling price, you pay the other bid:
        Your Payoff = Your Value - the Other Bid;
      - if the other bid is less than the minimum selling price, you pay the minimum selling price:
        Your Payoff = Your Value - the Minimum Selling Price;
    - 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. Therefore,
      - with 50% chance you get the object and pay the other bid:
        Your Payoff = Your Value - the Other Bid;
      - with 50% chance you don't get the object:
        Your Payoff = 0.
- **Auctioneers**: In each round, you will receive two bids from your group.
  - If both bids are less than your minimum selling price, the object is not sold, and :
    Your Payoff = 0;
  - if both bids are greater than or equal to your minimum selling price, you sell the object to the higher bidder and
    Your Payoff = the Lower Bid.
  - if one bid is greater than or equal to your minimum selling price and the other bid is less than your minimum selling price, you sell the object to the higher bidder and
    Your Payoff = the Minimum Selling Price.

- For example, if the minimum selling price is 1, bidder A bids 25, and bidder B bids 55, since $55 > 1$ and $55 > 25$, bidder B gets the object.
  Bidder A's payoff = 0;
  bidder B's payoff = bidder B's value - bidder A's bid = bidder B's value - 25;
  the auctioneer's payoff = 25.
- There will be 30 rounds. There will be no 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 all rounds.
- Bidders: the exchange rate is $1 for ____________ points.
- Auctioneers: the exchange rate is $1 for ____________ points.

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

Review Questions: you will have ten minutes to finish the review questions. Please raise your hand if you have any questions or if you finish the review questions. The experimenter will check each participant's answers individually. After ten minutes we will go through the answers together.

1. Suppose the minimum selling price is 1, your value is 60, and you bid 62.
   If the other bid is 59, you get the object. Your payoff = __.
   If the other bid is 61, you get the object. Your payoff = __.
   If the other bid is 70, you don't get the object. Your payoff = __.
2. Suppose the minimum selling price is 1, your value is 60, and you bid 60.
   If the other bid is 55, you get the object. Your payoff = __.
   If the other bid is 60,
   - with __ chance you get the object, your payoff = __;
   - with __ chance you don't get the object, your payoff = __.

   If the other bid is 70, you don't get the object. Your payoff = __.
3. Suppose the minimum selling price is 1, your value is 60, and you bid 57.
   If the other bid is 55, you get the object. Your payoff = __.
   If the other bid is 58, you don't get the object. Your payoff = __.
   If the other bid is 70, you don't get the object. Your payoff = __.
4. The minimum selling price is 30 and your bid is 25, your payoff = __.
5. True or false:
   (a) __If a bidder's value is 25, it must have been drawn from the low distribution.
   (b) __If a bidder's value is 60, it must have been drawn from the high distribution.
   (c) __You will be playing with the same two participants for the entire experiment.
   (d) __A bidder's payoff depends only on his/her own bid.
   (e) __If you are an auctioneer and your minimum selling price is higher than both bids, your payoff will be zero.

APPENDIX B. POST-EXPERIMENT SURVEY

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. For female participants only:
   - How many days away is your next menstrual cycle? ____
   - Do you currently experience any symptoms of PMS? (please choose one)
     - none ____
     - mild ____
     - severe ____

Table 1: Features of Experimental Sessions

Information Conditions	No. Subjects Per Session	Auction Mechanisms	Exchange Rates		Total No. Subjects
			Bidders	Auctioneers	
Known Distribution	8	1st Price	20	-	40
	8	2nd Price	20	-	40
	12	1st Price	12	60	60
	12	2nd Price	12	60	60
Unknown Distribution	8	1st Price	20	-	40
	8	2nd Price	20	-	40
	12	1st Price	12	60	60
	12	2nd Price	12	60	60

Table 2: Summary Statistics of Demographics, Educational Background and Menstrual Cycle for Bidders

Label	Variable	Obs.	Mean	Std. Dev.	Min	Max
(1)	Female	282	0.53	0.50	0	1
(2)	Age	282	20.87	2.81	18	41
(3)	Number of Siblings	282	1.55	1.23	0	9
(4)	Asian/Asian American	282	0.33	0.47	0	1
(5)	Other Ethnicities	282	0.13	0.34	0	1
(6)	Math and Stats Courses	282	1.99	2.23	0	20
(7)	Science and Engineering Courses	282	7.25	8.95	0	36
(8)	Economics and Business Courses	282	2.55	4.45	0	28
(9)	Other Social Science Courses	282	4.29	4.82	0	22
(10)	Humanities and Other Courses	282	7.17	7.43	0	44
(11)	Menstrual Phase	149	0.23	0.42	0	1
(12)	Follicular Phase	149	0.13	0.34	0	1
(13)	Peri-Ovulatory Phase	149	0.15	0.36	0	1
(14)	Luteal Phase	149	0.21	0.41	0	1
(15)	Pre-Menstrual Phase	149	0.28	0.45	0	1
(16)	PMS-none	149	0.79	0.41	0	1
(17)	PMS-mild	149	0.20	0.40	0	1
(18)	PMS-severe	149	0.01	0.08	0	1

Notes:
Summary statistics for menstrual cycle related variables are reported for women only.

Table 3: Correlations of Demographic, Education, and Menstrual Phase Variables for Bidders

		(1) Female	(2) Age	(3) Sibl.	(4) Asian	(5) Other	(6) MathStat	(7) SciEng	(8) EconBus	(9) Soc.Sci.	(10) Hum.	(11) Mens.	(12) Folli.	(13) Peri-Ovu.	(14) Luteal	(15) Premens
(1)	Female	1.00														
(2)	Age	-0.04	1.00													
(3)	No. Sibl.	-0.02	0.04	1.00												
(4)	Asian/As. Am.	-0.02	0.12**	-0.13**	1.00											
(5)	Other Ethn.	0.09	-0.04	0.09	-0.27***	1.00										
(6)	Math & Stats	-0.05	0.04	-0.06	0.13**	0.07	1.00									
(7)	Science & Eng.	-0.14**	0.07	0.07	-0.02	0.04	0.22***	1.00								
(8)	Econ. & Bus.	-0.04	-0.06	-0.08	0.14**	-0.02	0.23***	-0.17***	1.00							
(9)	Other Soc. Sci.	0.12**	0.07	0.00	-0.12**	-0.03	-0.10	-0.20***	0.09	1.00						
(10)	Hum. & Other	0.09	-0.17***	0.02	-0.19***	0.11*	-0.02	-0.10*	0.06	0.13**	1.00					
(11)	Menstrual	0.35***	-0.07	0.02	-0.03	0.05	-0.10	-0.08	-0.05	-0.02	0.02	1.00				
(12)	Follicular	0.26***	-0.09	-0.02	0.01	-0.03	0.01	-0.04	-0.06	0.00	0.02	-0.10*	1.00			
(13)	Peri-Ovulatory	0.28***	-0.02	-0.07	-0.02	0.08	-0.04	-0.08	0.07	0.14**	0.06	-0.11*	-0.08	1.00		
(14)	Luteal	0.33***	0.16***	0.04	0.09	0.00	-0.08	-0.06	0.00	0.07	0.05	-0.13**	-0.10	-0.10*	1.00	
(15)	Pre-Menstrual	0.39***	-0.07	-0.01	-0.08	0.05	0.11*	0.02	-0.02	0.01	0.01	-0.15**	-0.11*	-0.12**	-0.15**	1.00

Notes:
Significant at: * 10% level; ** 5% level; *** 1% level.

Table 4: Effect of Demographics, Education and Menstrual Cycle on Bids in the First-Price Auction.

Dependent variable (estimation method):	Bid in FPA (OLS)			
	(1)	(2)	(3)	(4)
Female	3.2036***	3.2243***		
	(0.6693)	(0.6455)		
Age	-0.0789	-0.0753	-0.1204	-0.1340
	(0.1351)	(0.1484)	(0.1083)	(0.1310)
Number of Siblings	-0.7712***	-0.7222**	-0.7695**	-0.7072**
	(0.2515)	(0.2584)	(0.2787)	(0.2807)
Asian/Asian American	-1.3131	-1.6614*	-1.6345*	-1.9988**
	(0.8563)	(0.8957)	(0.8365)	(0.9022)
Other Ethnicities	1.2088	1.3586	1.4613	1.5130
	(0.9906)	(0.9922)	(1.0223)	(1.0206)
Math and Stats Courses		0.0231		0.0538
		(0.1606)		(0.1763)
Science and Engineering Courses		-0.0685*		-0.0473
		(0.0370)		(0.0350)
Economics and Business Courses		-0.0069		0.0076
		(0.0806)		(0.0735)
Other Social Science Courses		-0.0910*		-0.1086*
		(0.0504)		(0.0572)
Humanities and Other Courses		-0.0349		-0.0371
		(0.0338)		(0.0326)
Menstrual Phase			2.3304	2.1983
			(1.5285)	(1.5231)
Follicular Phase			6.3321***	6.2230***
			(1.1061)	(0.9396)
Peri-Ovulatory Phase			2.6858**	3.0796**
			(1.1283)	(1.2834)
Luteal Phase			4.0420***	4.2065***
			(1.1208)	(1.2088)
Pre-Menstrual Phase			1.5365**	1.5904*
			(0.7276)	(0.7845)
Observations	3,463	3,463	3,463	3,463
R-squared	0.83	0.83	0.83	0.83

Notes:

1: Clustered standard errors (at session level) in parentheses.

2: Significant at: * 10% level; ** 5% level; *** 1% level.

3: Cubic polynomial in value and reserve price is controlled for.

4: Period indicator variables are used to control for learning.

Table 5: Effect of Demographics, Education and Menstrual Cycle on Dominant Strategy Play in the Second-Price Auction.

Dependent variable (estimation method):	Playing Dominant Strategy in SPA (Logit)			
	(1)	(2)	(3)	(4)
Female	-0.3688	-0.2456		
	(0.3597)	(0.3265)		
Age	0.0452	0.0555	0.0365	0.0469
	(0.0293)	(0.0364)	(0.0320)	(0.0361)
Number of Siblings	-0.1140	-0.1362	-0.1380	-0.1629
	(0.1112)	(0.1144)	(0.1138)	(0.1136)
Asian/Asian American	-0.3307	-0.5335	-0.4176	-0.6193*
	(0.2792)	(0.3254)	(0.2916)	(0.3465)
Other Ethnicities	-0.7799**	-0.8087**	-0.8307**	-0.8631**
	(0.3607)	(0.3692)	(0.3389)	(0.3485)
Math and Stats Courses		-0.0968		-0.0923
		(0.0777)		(0.0814)
Science and Engineering Courses		0.0187		0.0196
		(0.0200)		(0.0205)
Economics and Business Courses		0.0730*		0.0744*
		(0.0377)		(0.0392)
Other Social Science Courses		-0.0436*		-0.0450*
		(0.0257)		(0.0255)
Humanities and Other Courses		-0.0117		-0.0120
		(0.0204)		(0.0197)
Menstrual Phase			-0.4500	-0.2901
			(0.5013)	(0.4972)
Follicular Phase			-0.6106	-0.5773
			(0.5658)	(0.5776)
Peri-Ovulatory Phase			-0.7548	-0.7163
			(0.6399)	(0.4561)
Luteal Phase			0.1291	0.2604
			(0.5466)	(0.5555)
Pre-Menstrual Phase			-0.4675	-0.2256
			(0.5397)	(0.4475)
Observations	3,463	3,463	3,463	3,463
Log-likelihood	-1,988.69	-1,942.11	-1,977.34	-1,925.45

Notes:

1: Clustered standard errors (at session level) in parentheses.

2: Significant at: * 10% level; ** 5% level; *** 1% level.

3: Period indicator variables are used to control for learning.

Table 6: Effect of Demographics, Education and Menstrual Cycle on Overbidding in the Second-Price Auction

Dependent variable (estimation method):	Overbidding (Logit)			
	(1)	(2)	(3)	(4)
Female	-0.2391	-0.3865		
	(0.2768)	(0.2687)		
Age	-0.0822	-0.0791	-0.0780	-0.0739
	(0.0517)	(0.0529)	(0.0565)	(0.0578)
Number of Siblings	0.0990	0.1201	0.1128	0.1353
	(0.1060)	(0.1013)	(0.1036)	(0.0962)
Asian/Asian American	0.4673*	0.6293**	0.5641**	0.7371**
	(0.2692)	(0.3027)	(0.2650)	(0.3097)
Other Ethnicity	0.4801	0.4534	0.5349*	0.5219
	(0.3233)	(0.3485)	(0.3205)	(0.3457)
Math and Stats Courses		0.0918		0.0866
		(0.0721)		(0.0756)
Science and Engineering Courses		-0.0209		-0.0215
		(0.0138)		(0.0145)
Economics and Business Courses		-0.0592**		-0.0586**
		(0.0284)		(0.0279)
Other Social Science Courses		0.0250		0.0270
		(0.0273)		(0.0268)
Humanities and Other Courses		0.0210		0.0227
		(0.0213)		(0.0212)
Menstrual Phase			-0.2103	-0.3917
			(0.4481)	(0.4519)
Follicular Phase			-0.0253	-0.0754
			(0.4277)	(0.4365)
Peri-Ovulatory Phase			-0.1975	-0.3161
			(0.3802)	(0.3603)
Luteal Phase			-0.6541	-0.8331**
			(0.4448)	(0.4156)
Pre-Menstrual Phase			0.0022	-0.2111
			(0.3982)	(0.3643)
Observations	3,463	3,463	3,463	3,463
Log-likelihood	-2060.18	-2021.64	-2038.42	-1991.58

Notes:
1: Clustered standard errors (at session level) in parentheses.
2: Significant at: * 10% level; ** 5% level; *** 1% level.
3: Period indicator variables are used to control for learning.

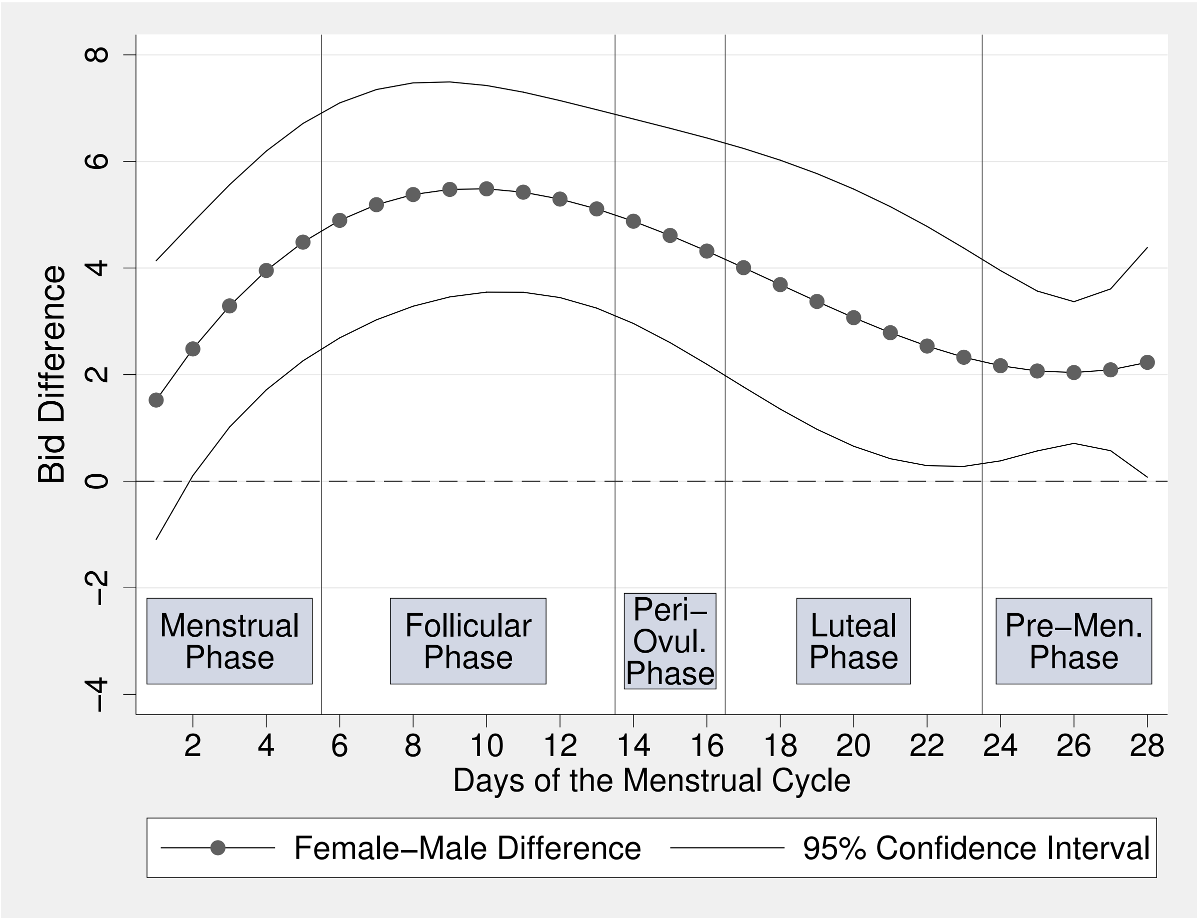

Figure 1: Menstrual Phases and Female-Male Bid Differences in the First-Price Auction