The Visible Hand: Finger Ratio (2D:4D) and Competitive Bidding*

Matthew Pearson[†] Burkhard C. Schipper[‡]

This version: October 31, 2011
First version: August 12, 2009

Abstract

In an experiment using two-bidder first-price sealed bid auctions with symmetric independent private values and 400 subjects, we scan also the right hand of each subject. We study how the ratio of the length of the index and ring fingers (2D:4D) of the right hand, a measure of prenatal hormone exposure, is correlated with bidding behavior and total profits. 2D:4D has been reported to predict competitiveness in sports competition (Manning and Taylor, 2001, and Hönekopp, Manning, and Müller, 2006), risk aversion in lottery tasks (Dreber and Hoffman, 2007, Garbarino et al., 2010), and the average profitability of high-frequency traders in financial markets (Coates, Gurnell, and Rustichini, 2009). We do not find any significant correlation between 2D:4D on either bidding or profits. However, there might be racial differences in the correlation between 2D:4D and bidding and profits.

Keywords: Hormones, Digit ratio, 2D:4D, Risk behavior, Competition, Competitive behavior, Auctions, Bidding, Endocrinological economics.

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

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*We are grateful to the editor, Jordi Brandts, and two anonymous referees for very helpful comments. We thank Yan Chen for providing us the z-tree programs of her experiment. Financial support by the Institute of Governmental Affairs, UC Davis, and the UC Davis Hellman Fellowship is gratefully acknowledged. We thank Coren Apicella, Nicole Baran, Giacomo Bonanno, Anna Dreber, Doug Miller, and participants in the 2009 Workshop on Neuroeconomics and Endocrinological Economics at UC Davis. Moreover, we thank Gabriel Mathy, Wen Yong Tang, and Nick Zolas for excellent research assistance.

[†]Department of Economics, University of California, Davis, Email: pearson@ucdavis.edu

[‡]Department of Economics, University of California, Davis. Email: bcschipper@ucdavis.edu

1 Introduction

To what extent are economic behavior and outcomes biologically determined? Which biological factors affect economic behavior? There is a growing literature with empirical evidence that biological factors substantially influence economic outcomes. Apart from the well known gender wage gap (see for instance Blau and Kahn, 2000) and evidence that on average tall men earn more than shorter men (Case and Paxson, 2008) and that attractive people earn on average more than less attractive people (Hamermesh and Biddle, 1994), there is also evidence that points to more specific biological mechanisms such as certain hormones or certain genes that determine economic behavior to some extent. For instance, Apicella et al. (2008) find that risk-taking in an investment decision is positively correlated with salivary testosterone levels in men. In the same investment decision task, Dreber et al. (2009) associate significantly more risk-taking behavior of men with the presence of the 7-repeat allele of the dopamine receptor D_4 gene. Using a lottery choice task in a design with monozygotic and dizygotic twins, Cesarini et al. (2009) conclude that risk preferences are to a certain extent heritable. Finally, Zak, Kurzban, and Matzner (2005) report that blood plasma levels of oxytocin are positively correlated with trustworthy behavior in a trust game and Kosfeld et al. (2005) observes that exposing humans to the hormone oxytocin increases trust. Zak et al. (2009) show that exposing men to testosterone decreases generosity in the ultimatum bargaining game.

In this study we investigate to what extent competitive behavior may be influenced by prenatal exposure to hormones such as testosterone and estrogen. That is, we are interested in what sense competitive behavior may be influenced by biological events before birth. We use as a proxy the "visible hand," that is the ratio between the length of the 2nd (index) finger and the 4th (ring) finger of the subjects' right hand (so called "digit ratio" or more precisely, 2D:4D). (See Manning, 2002, for an introduction.) 2D:4D is positively correlated with prenatal exposure to estrogen and negatively correlated to prenatal exposure to testosterone (Manning et al., 1998, Lutchmaya et al., 2004, Hönekopp et al., 2007). On average, men have lower 2D:4D than women. 2D:4D is to a large extent genetically determined (Paul et al., 2006), but it may also be affected by the environment *in utero*. In any case, 2D:4D is determined before birth and thus before common economic, social, and cultural factors could shape competitive behavior of the individual directly.

There is already some indirect empirical evidence that 2D:4D may predict competitive behavior. Manning and Taylor (2001) and Hönekopp, Manning, and Müller (2006) show that lower 2D:4D predicts more competitiveness in sports, but they do not address whether this result is due to a correlation with physical fitness or mental "competitiveness." Dreber and Hoffman (2007) and Garbarino et al. (2011) show that risk-taking in lottery tasks is significantly negatively correlated with 2D:4D in White subjects but Apicella et al. (2008) and Schipper (2011b) show that this is not the case in more ethnically mixed samples. It is known that there are differences in 2D:4D between ethnic groups (Manning, et al., 2002, Manning et al., 2004). 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 in females of a sample of 550 MBA students. Brañas Garza and Rustichini (2011) study the correlation between 2D:4D, risk aversion, and abstract reasoning ability. They employ two measures of risk aversion in a sample of 188 Caucasian subjects. Their analysis reveals that whether or not one can find a significant correlation between risk aversion and the digit ratio may depend on the measure of risk aversion employed. However, the focus of their study is on how prenatal hormone exposure may affect risk aversion indirectly through abstract reasoning ability. Using mediation analysis, they conclude that the digit ratio effects risk aversion directly and indirectly through abstract reasoning ability.

Both "competitiveness" and risk-taking behavior are relevant for our study. We investigate the correlation between 2D:4D and bidding behavior and profits in sealed bid first-price auctions with symmetric independent private values. From auction theory it is known that higher risk-taking[1] in those auctions amounts to relatively lower bids (see Krishna, 2002, Chapter 4.1). A higher bid implies a higher probability of winning the object. Yet, conditional on winning, a higher bid results in a lower profit in the first-price auction. Thus we hypothesize that 2D:4D is positively correlated with bids and negatively correlated with profits.[2]

The study most relevant to ours is Coates, Gurnell, and Rustichini (2009), who find that lower 2D:4D predicts the 20-month average profitability of 44 male high-frequency traders in London. We however, do not find a significant correlation of both competitive bidding and profits with 2D:4D in repeated sealed bid first-price auctions played by 400 college students. While the study by Coates, Gurnell, and Rustichini (2009) is clearly related to ours, there are several important differences that may account for the contrasting results. First, Coates, Gurnell, and Rustichini (2009) focus on a sample of males in a highly selected profession while we focus on a diverse sample of college students. It could be that among a highly competitive subsample of the population lower 2D:4D is correlated with competitiveness while such an relation is absent in the overall population. Second, high frequency traders compete under time pressure in a complex environment while such an intense pressure and complexity are absent in the sealed bid first-price auction. That is, the social environment and the underlying market game differs from our auction experiment. In Section 4, we will discuss in more detail how the differences in the market games may contribute to the different results. Third, the performance index in Coates, Gurnell, and Rustichini (2009) is cumulated profits and losses over a period

[1]We use the term "risk-taking" in a broader sense to refer to all dispositions that are behaviorally indistinguishable from risk in the first-price auction such as anticipated looser regret (see Filiz and Ozbay, 2007) or relative payoff concerns (see Morgan et al., 2003). For a discussion of experimental evidence for risk aversion in first-price auctions, we refer to Kagel (1995, Chapter 7 I.G).

[2]Research on aggressive behavior and 2D:4D may also be suggestive for a potential connection between competition and 2D:4D. Benderlioglu and Nelson (2004) find a correlation between lower 2D:4D and the higher force of hanging up the phone and the choice of a more aggressive language of a letter after an unsuccessful charity solicitation in females but not in males. In contrast, Bailey and Hurd (2005) find that lower 2D:4D is correlated with higher aggression evaluated with a questionnaire in males but not females. We thank an anonymous referee for suggesting these references.

of one year, which tends to reduce the impact of noise.[3] Forth, the stakes are different. Successful traders earn more than £4 million per year while subjects in our study earned on average about US$19.00.

Ours is not the first study of 2D:4D in experimental games. 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 ratio 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.

We are also not the first to study how biological factors affect bidding in auctions. Casari, Ham, and Kagel (2007) report significantly different bidding behavior of men and women in sealed bid first-price common value auctions. Initially, women bid significantly higher than men and hence are more prone to the winner's curse. However, women also learn bidding much faster than men, thus eventually their earnings may even 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 (2009) study the effect of the menstrual cycle on bidding behavior of women in sealed bid first and second-price auctions with independent private values. They 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, in the first-price auction, higher bidding in the follicular phase and lower bidding in the luteal phase is driven entirely by oral hormonal contraceptives. No such differences appear for second-price private value auctions. These findings are contrasted in a follow-up paper by Pearson and Schipper (2011) who report that naturally cycling women bid significantly higher than men and earn significantly lower profits than men except during the midcycle when fertility is highest. They suggest an evolutionary hypothesis according to which women are hormonally predisposed to behave generally more riskily during their fertile phase of their menstrual cycle in order to increase the probability of conception, quality of offspring, and genetic variety. They also find that women on hormonal contraceptives bid significantly higher and earn substantially lower profits than men. Finally, using a subsample of the current paper Schipper (2011a) shows that bidding is positively correlated with salivary progesterone and profits are negatively correlated with salivary progesterone. No significant correlations with salivary testosterone, estradiol, or cortisol are found. In both Pearson and Schipper (2011) and Schipper (2011a), we use the same auction environment as in Chen, Katuščák, and Ozdenoren (2007, 2009) and in this paper.

The paper is organized as follows: In Section 2 we outline the experimental design. The analysis of the data is presented in Section 3. We finish in Section 4 we a discussion of our null finding. Access to the Stata datasets and a do-file that reproduces the entire

[3] We thank a referee for emphasizing this point.

analysis reported here and additional analysis is provided through `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 the 2D:4D. Experimental auctions offer an advantage over data from real-world auctions in that we can induce and control for the valuations of the object. In equilibrium, the bidding strategy is a monotone increasing function of valuations (see Krishna, 2002).

Every session of the experiment was divided into four relevant phases: instructions, bidding, questionnaire, and a scan of the right hand.

Instructions: At the beginning of each session, subjects were randomly assigned to a computer terminal. After signing a consent form, 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 since the goal of the study is not to test for a correlation between 2D:4D and the comprehension of the auction game but rather for the correlation between 2D:4D and behavior in auctions.

Bidding: Subjects repeatedly played a two-bidder first-price sealed bid auction with symmetric independent private values drawn from a piecewise linear distribution function constructed as follows: A bidder's valuation is drawn 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

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

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

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 wining 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 the object 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. (For screen shots, see Pearson and Schipper, 2011.)

Questionnaire: At the end of the session, subjects completed a questionnaire on demographic information and the menstrual cycle. Data with regard to the menstrual cycle are analyzed in Pearson and Schipper (2011).

Scanning of the right hand: At the end of the experiment, each subject's right hand (and the right hand only) was scanned with a conventional office image scanner. The purpose of the hand scan is to measure the length of the 2nd and 3rd finger and analyze the digitratio (2D:4D). The second and fourth digits were later measured independently by two separate researchers from the center of the flexion crease proximal to the palm to the top of the digit using the measurement tools in Adobe Photoshop and Gimp. When measuring the fingers, the researchers did not know whether the hand belong to a male or female subject or how this subject behaved in the experiment. The measures used here are based on the averages of both measurements for each finger of each subject respectively.

The auctions were programmed in z-tree (Fischbacher, 2007). We used the same software program as Chen, Katuščák, and Ozdenoren (2007, 2009). We are very grateful to Yan Chen for providing us the program. The experiment was conducted in two waves at the Social Science and Data Service Lab at UC Davis, 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 before and after the experiment, a behavioral risk measure using a Holt-Laury task for gains and losses, and further demographic information. The analysis of those additional measures of 2010 sample is presented in two companion papers, Schipper (2011a, b). Subjects were recruited from the student population of UC Davis using Orsee (Greiner, 2004).

On average, our subjects earned \$14.43 (standard deviation 7.82, minimum \$-7.38, maximum \$38.85) over all auction rounds. This amount excludes the \$5.00 dollar show up fee for every subject and any other earnings from the lottery task in the 2010 sample (see Schipper, 2011a, b). Because of these additional 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 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

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

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	

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]

Table 2 presents the summary statistics of the digit ratio by gender and ethnicity.[6] Average 2D:4D of males is significantly lower than of females ($t = -3.763$, $p < 0.01$).

[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". Another reason could be that Asians were more attracted to our experiments. For instance, Loo et al. (2008) surveying the literature on Chinese gambling find that gambling is widespread preferred form of entertainment among Chinese.

[6]For one subject, we accidently measure the left hand. For this subject we include here the digit ratio of the left hand. Our results remain unchanged when we drop this subject from the analysis.

Table 2: Digit Ratio

Variable		Number	Mean	Std. Dev.	Max	Min
White	Male	86	0.955	0.027	0.895	1.022
	Female	48	0.966	0.028	0.898	1.036
	Total	134	0.959	0.028	0.895	1.036
Asian	Male	105	0.946	0.028	0.882	1.006
	Female	123	0.961	0.027	0.880	1.033
	Total	228	0.954	0.028	0.880	1.033
Hispanic	Male	17	0.944	0.030	0.892	1.002
	Female	11	0.951	0.038	0.898	1.001
	Total	28	0.947	0.033	0.892	1.002
Black	Male	5	0.950	0.010	0.941	0.962
	Female	3	0.940	0.026	0.917	0.968
	Total	8	0.946	0.017	0.917	0.968
Others	Male	9	0.962	0.043	0.895	1.024
	Female	14	0.975	0.039	0.902	1.042
	Total	23	0.970	0.040	0.895	1.042
All	Male	213	0.951	0.029	0.882	1.024
	Female	187	0.961	0.029	0.880	1.042
	Total	400	0.956	0.029	0.880	1.042

This holds both for the White ($t = -2.157$, $p = 0.02$) and Asian subsamples ($t = -3.924$, $p < 0.01$). No differences between the digit ratio of males and females are significant for the Hispanic, Black or Other subsamples. The Hispanic, Black, and Other subsamples are too small to draw meaningful conclusions.

3 Results

For our analysis, we fix two 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 to eight subjects, we have 50 clusters and thus 50 independent observations.

Second, each specification of regressions on bids also includes a cubic polynomial[7] in

[7]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). 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 term.

the value and a set of auction round indicators to control for learning.[8] 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. In order to save space, 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.

We estimate versions of the following parametric model for bids:

$$b_{i,t} = \beta_0 + \beta_1 v_{i,t} + \beta_2 v_{i,t}^2 + \beta_3 v_{i,t}^3 + \delta_t p_t + \nu n_i + \zeta X_i + \theta d_i + \varepsilon_{i,t},$$

where $b_{i,t}$ is the bid of subject i at auction round $t = 1, ..., 30$, β_0 is a constant, $v_{i,t}$ is the value of subject i at auction round t, p_t is a set of auction round dummies, n_i is a dummy that is one if i is in the 2010 sample, X_i is a vector of demographic variables including gender, age, race, number of siblings, and majors of study depending on the specification, and d_i is subject i's digit ratio. $\varepsilon_{i,t}$ is the unobserved error term of subject i in round t (clustered on the session level). Analogously, we estimate a parametric model for total dollar profits (summed over all rounds) in which we drop the round dummies and the cubic polynomial in the value and add the mean, variance, and skewness of the subject's empirical distribution of values as regressors. For robustness checks, we consider similar specifications in which we will drop or add some demographics variables and control for session fixed effects.

Table 3 provides results for the entire sample of 400 subjects. There is a strong gender effect for both bids and profits. On average, women bid 2.3 points higher than men and earn 3.93 dollars less than men. This gender effect has been reported already in Pearson and Schipper (2011), where we trace it back to the menstrual cycle. Similar gender effects have been reported in Casari, Ham, and Kagel (2008), Ham and Kagel (2006), and Chen, Katuščák, and Ozdenoren (2009).

We see in Table 3 that 2D:4D does not significantly influence bidding or profits. Moreover, in comparing the first and second regressions (and the third and fourth regressions) we conclude that the digit ratio does not absorb the gender effect. In fact, even if gender is omitted (not reported in Table 3), then 2D:4D is just marginally significant (p = 0.084). In this regression, 2D:4D contains the information on gender since 2D:4D is significantly larger for females as compared to males. Moreover, dropping variables for choice of major of study does not change the results nor does the omission of the variable for the number of siblings (not reported in Table 3). We conclude that "the visible hand is invisible," or more formally:

Observation 1 *The 2D:4D is not significantly correlated with bidding behavior or profits in the full sample.*

[8] 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.

Table 3: Full Sample

	(bids)	(bids)	(profits)	(profits)
Digit Ratio		7.469		−9.626
		(7.748)		(14.072)
Female	2.342***	2.141***	−3.927***	−3.531***
	(0.468)	(0.525)	(0.657)	(0.774)
Age	−0.106	−0.115	0.187	0.206
	(0.082)	(0.081)	(0.150)	(0.149)
Asian	−1.108**	−0.916*	1.068	0.753
	(0.471)	(0.478)	(0.671)	(0.738)
Other	−0.388	−0.406	−0.169	−0.185
	(0.872)	(0.854)	(1.369)	(1.320)
Observations	12000	12000	400	400
R^2	0.85	0.85	0.25	0.26

Standard errors (clustered at the session level) in parentheses. Significance levels: *10%; ** 5%; *** 1%. We suppress from the report coefficients for num. of siblings, mathematics, science & engin., economics, social science, humanities, the dummy for the 2010 sample as well as the qubic polynomial in value and period indicators (bids), and the mean, standard deviation, and skewness of the empirical distribution of values (profits).

Since 2D:4D is dimorphic with respect to gender, we may obtain significant effects when separating our sample by gender. In fact, some prior studies of the digit ratio in psychology have found significant effects of 2D:4D for men but not for women.[9]

Table 4 presents results separated by gender. Again, there are no significant effects of 2D:4D on bidding behavior and profits. This holds also when dropping controls for major of study or the number of siblings (not reported in Table 4). We conclude:

Observation 2 *The 2D:4D is not significantly correlated with bidding behavior or profits in either male or female subsamples.*

It is known from prior studies of the correlation between the digit ratio and risk-taking that effects of 2D:4D may depend on ethnic groups. Dreber and Hoffman (2007) and Garbarino et al. (2011) show that risk-taking in investment tasks are significantly negatively correlated with 2D:4D in Caucasian subjects while Apicella et al. (2008) and Schipper (2011b) show that this is not the case in racially more mixed samples. Therefore we separately analyzed the two major ethnic groups in our sample, Whites and Asians. The results are reported in Table 5.

There is a significant effect of the digit ratio on bids for the White subsample ($p = 0.033$), but no significant effect on profits. Moreover, the effect is negative, which is

[9]For instance, see Sanders et al. (2005) for a mental rotation task. Perhaps more closely related to our study, Benderlioglu and Nelson (2004) find a correlation between lower 2D:4D and a behavioral measure of aggressiveness in females but not in males. In contrast, Bailey and Hurd (2005) find that lower 2D:4D is correlated with a higher survey measure of aggression in males but not females.

Table 4: Sample Separated by Gender

	(bids-female)	(profits-female)	(bids-male)	(profits-male)
Digit Ratio	9.355	−12.136	7.840	−5.775
	(12.926)	(19.763)	(7.796)	(15.209)
Age	−0.001	0.144	−0.238**	0.286
	(0.113)	(0.163)	(0.117)	(0.215)
Asian	−1.595**	1.450	−0.496	0.505
	(0.745)	(1.127)	(0.634)	(1.103)
Other	−1.604	2.083	0.067	−1.408
	(1.257)	(1.686)	(1.057)	(1.643)
Observations	5610	187	6390	213
R^2	0.85	0.20	0.86	0.26

Standard errors (clustered at the session level) in parentheses. Significance levels: *10%; ** 5%; *** 1%. We suppress from the report coefficients for num. of siblings, mathematics, science & engin., economics, social science, humanities, the dummy for the 2010 sample as well as the qubic polynomial in value and period indicators (bids), and the mean, standard deviation, and skewness of the empirical distribution of values (profits).

Table 5: White and Asian Subsamples

	(bids-white)	(profits-white)	(bids-asian)	(profits-asian)
Digit Ratio	−21.853**	27.249	21.918*	−30.216
	(9.960)	(17.808)	(12.190)	(19.121)
Female	3.588***	−5.352***	1.608**	−3.177***
	(0.767)	(1.288)	(0.706)	(1.035)
Age	−0.253**	0.239	−0.052	0.253
	(0.095)	(0.245)	(0.139)	(0.211)
Observations	4020	134	6840	228
R^2	0.88	0.34	0.84	0.26

Standard errors (clustered at the session level) in parentheses. Significance levels: *10%; ** 5%; *** 1%. We suppress from the report coefficients for num. of siblings, mathematics, science & engin., economics, social science, humanities, the dummy for the 2010 sample as well as the qubic polynomial in value and period indicators (bids), and the mean, standard deviation, and skewness of the empirical distribution of values (profits).

contrary to what one would expect. If a lower digit ratio is correlated with higher circulating testosterone (Manning et al., 1998) and higher circulating testosterone is correlated with higher risk-taking (Apicella et al., 2008), then we should expect that a lower digit ratio is correlated with lower bids and higher profits.[10] We observe exactly the opposite for the White subsample. The finding with respect to bids of Whites is robust to dropping controls for demographics (except gender) and to additionally controlling for session fixed effects. The effect on bids for the Asian subsample is only marginally

[10]See Section 4 for a more detailed discussion of how the digit ratio may effect bidding and profits.

significant ($p = 0.078$) and insignificant for profits, but the sign of both coefficients are in the expected direction. The effect of the digit ratio on bids for the Asian subsample remains marginally significant when dropping all demographics controls but gender ($\beta = 23.85$, $p = 0.054$) but becomes insignificant if additionally we control for session fixed effects ($\beta = 12.58$, $p = 0.315$).

Note that both the results by Manning et al. (1998) and Apicella et al. (2008) are for males only. This led us to study the male and female subsamples of both ethnic groups further. In Table 6 we separated the White subsample further into the White male subsample and the White female subsample. We observe that the coefficient for 2D:4D looses significance both for in male and female subsamples. This may be due to the smaller sample sizes.

Table 6: White Subsamples

	(bids-male)	(profits-male)	(bids-female)	(profits-female)
Digit Ratio	−25.186	38.982	−13.128	16.554
	(15.046)	(26.732)	(14.584)	(27.291)
Age	−0.206	0.101	−0.332**	0.410
	(0.159)	(0.375)	(0.122)	(0.268)
Observations	2580	86	1440	48
R^2	0.89	0.28	0.88	0.26

Standard errors (clustered at the session level) in parentheses. Significance levels: *10%; ** 5%; *** 1%. We suppress from the report coefficients for num. of siblings, mathematics, science & engin., economics, social science, humanities, the dummy for the 2010 sample as well as the qubic polynomial in value and period indicators (bids), and the mean, standard deviation, and skewness of the empirical distribution of values (profits).

Interestingly, we see in Table 5 that age is statistically significant for the bids of the White subsample although the size of the coefficient is small. It appears that the older the student, the lower are his or her bids on average. Table 6 suggests that this is due to White female students in our sample. Yet, the number of observations is rather low since we just have 48 White female students among our subjects.

Table 7 shows the results for our subsample of Asian students. The digit ratio is significant for bids of Asian males ($p = 0.016$). This finding is also in the expected direction, that is, the lower the digit ratio the lower the bids. It does not translate into significantly larger profits. There is no significant correlation between the digit ratio and the profits for Asian males. Moreover, we don't find any significant correlation for Asian females.

Interestingly, we see in Table 7 that age is statistically significant for profits of Asian males (but only marginally significant for their bids). On average, an increase of one year of age increases profits for about \$0.72. This is somewhat different to Whites, where we find a correlation only for bids of females.

The digit ratio may interact with ethnicity. It is known that there are differences in

Table 7: Asian Subsamples

	(bids-male)	(profits-male)	(bids-female)	(profits-female)
Digit Ratio	32.367**	−34.945	12.867	−19.826
	(12.920)	(23.360)	(19.982)	(27.019)
Age	−0.365*	0.718**	0.118	0.007
	(0.186)	(0.295)	(0.144)	(0.225)
Observations	3150	105	3690	123
R^2	0.84	0.34	0.84	0.17

Standard errors (clustered at the session level) in parentheses. Significance levels: *10%; ** 5%; *** 1%. We suppress from the report coefficients for num. of siblings, mathematics, science & engin., economics, social science, humanities, the dummy for the 2010 sample as well as the qubic polynomial in value and period indicators (bids), and the mean, standard deviation, and skewness of the empirical distribution of values (profits).

2D:4D between ethnic groups (Manning, et al., 2002, Manning et al., 2003, Manning et al., 2004). Recall that Dreber and Hoffman (2007) (and similarly Garbarino et al., 2011) report significantly more risk-taking in an investment task for lower 2D:4D in White subjects but Apicella et al. (2008) show that this is not the case in a more ethnically mixed sample (see also Schipper, 2011b, for a study using a subsample of this paper).

Implicitly our analysis involves multiple testing. Since we consider four groups, White males, White females, Asian males, and Asian females, there is a relatively large chance that we find some "significant" correlation between bidding or profits and the digit ratio 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 the family of race-gender pairs is 5%, the Bonferroni corrected significance level for each race-gender pair should be 1.25% (since there are four such groups). Since the result for Asian males is individually significant only at 1.6%, we conclude that our result is just marginally significant if Bonferroni correction is used. Similarly, we should reconsider the result for Whites in Table 5. There we implicitly test among two groups, Whites and Asians. If the desired significance level for the family of ethnicities is 5%, the Bonferroni corrected significance level for each phase should be 2.5% (since there are two groups). Yet, the coefficient for Whites in the regression on bids is individually significant only at 3.3%. Again, the result is marginally significant. Additional observations may yield sharper results.

Observation 3 *The evidence on 2D:4D and bidding and profits with regard to White and Asian subsamples is inconclusive. There is a marginal significant negative correlation between 2D:4D and bids of Whites when controlling for gender and demographics as well as a marginal significant positive correlation between 2D:4D and bids of Asian males when controlling for demographics. These correlations are insignificant if controlled for multiple testing.*

The digit ratio may have an effect on competitive bidding in interaction with other variables.[11] For instance, it is conceivable that the digit ratio is negatively correlated with bidding only when values are relatively high. Especially when values are relatively high and the bidder could eventually win the auction with a bid close to her value, the risky disposition to bid relatively low may be negatively correlated with the digit ratio. To examine such a possibility, we introduce the interaction term "digit ratio × low value" as a regressor in the parametric model, where "low value" is a dummy variable indicating a value between 0 and 50. Given this interaction, the coefficient for the digit ratio then measures the correlation of the digit ratio and bids if values are relatively high (i.e., when the variable "low value" is zero).[12] Table 8 in the appendix reports the results for the entire sample, by gender, and by major ethnic subsamples. We do find that our previous observations for different ethnicities hold also for high values. Moreover, the interaction term is not significant.

Another plausible interaction may be with the auction rounds. An effect of digit ratio may be associated with learning over time. To examine this possibility, we introduce the interaction term "digit ratio × late bids" as a regressor in the parametric model, where "late bids" are defined as bids submitted in rounds 16 to 30. Given this interaction, the coefficient for the digit ratio measures then the correlation between the digit ratio and bids in rounds 1 to 15 (i.e., when the variable "late bids" is zero). Table 9 in the appendix reports the results for the entire sample (full), by gender, and by major ethnic subsamples. Moreover, the last specification in Table 9 suggests that our finding for Whites in Table 5 may be due to early bids of White males. Again, the sign of the coefficient is negative, which is contrary to what we would expect if higher digit ratios are correlated with lower levels of circulating testosterone which in turn is correlated with higher risk aversion.

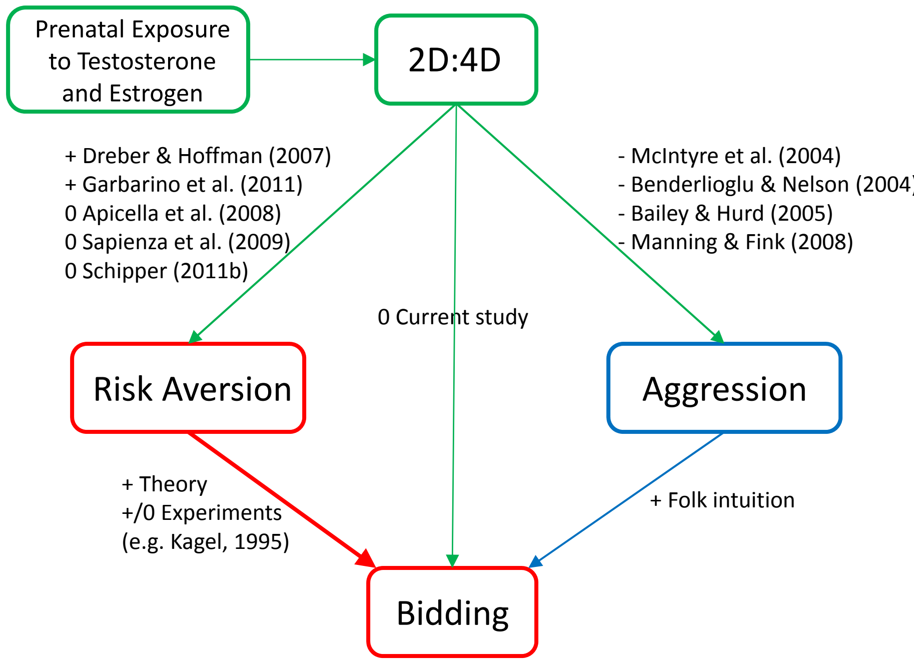
4 Discussion

What are exactly the mechanisms of how prenatal exposure to testosterone and estrogen as measured by 2D:4D could effect competitive bidding? We can think of two channels. On one hand, 2D:4D has been shown to be positively correlated with risk aversion in some studies. Apicella et al. (2008) and Schipper (2011b) do not find significant correlations between 2D:4D and risk aversion in racially mixed samples, while in contrast, Dreber and Hoffman (2007) and Garbarino et al. (2011) do find significant positive correlations between the digit ratio and risk aversion in Caucasian samples. Auction theory predicts that risk aversion is increasing bids in first-price auctions with independent private values although the experimental evidence is mixed (see for a survey Kagel, 1995). On the other hand, 2D:4D is negatively correlated with psychological notions of "aggression". Bailey and

[11]We thank an anonymous referee to encouraging us to study possible interaction effects.

[12]The interaction with a dummy variable is more meaningful than an interaction with the value or the mean-centered value since the probability of having any particular value is relatively low. A value of zero is excluded by design and drawing the mean value is rare for a bidder.

Figure 1: Possible Channels



Hurd (2005) find that lower 2D:4D is correlated with a higher survey measure of aggression in males but not females. Benderlioglu and Nelson (2004) find a correlation between lower 2D:4D and a behavioral measure of aggressiveness in females but not in males. McIntyre et al. (2007a) report that lower 2D:4D is correlated with unprovoked attacks in a simulated war game. Using a large internet survey with self-reported measurements of fingers, Manning and Fink (2008) find a negative correlation between 2D:4D and a survey-based measure of dominance. While the psychological notion of "aggression" is not formally defined, we would argue that folk intuition suggests a positive correlation between "aggression" and bidding in auctions. "Aggression" is often associated with the intention to harm others or to dominate others (Archer, 1991, Mazur and Booth, 1998). This may point to relative payoff concerns. It is known from Morgan et al. (2003) that relative payoff concerns increase bidding above risk neutral Nash equilibrium similar to risk aversion in first-price auctions with independent private values. Thus, we have two conflicting predictions. The risk aversion channel suggests that 2D:4D should be positively correlated with bidding in first-price auctions, while the aggression channel suggestions that 2D:4D should be negatively correlated with bidding. Figure 1 provides an overview over the two possible channels. Green refers to the biological level, blue to the psychological level, and red to the economic level. Arrows indicate correlations and the weight may indicate our knowledge of those effects. Beside the arrows we cite evidence for those effects. We indicate a positive correlation with a "+", a negative correlation with a "–", and a null finding with "0".

Equipped with the conceptual heuristic depicted in Figure 1, we can think of four reasons for our null finding: First, both channels are at work and their effects counter each other. There may be other contexts in which this is not the case. We would argue that for instance in the context of financial trading, risk aversion generates behavior that one may reasonable call less "aggressive". Thus, in the financial trading context of Coates, Gurnell, and Rustichini (2009), 2D:4D may have the same effect on behavior both via the risk aversion channel and via the "aggression" channel. This may explain why we observe a null result in first-price auctions with independent private values but Coates, Gurnell, and Rustichini (2009) report a significant negative correlation between 2D:4D and financial trading profits.

A second reason could be that both effects are non-existent in the auction task. On one hand, the association between 2D:4D and risk aversion is not that clear given several null results in the literature. Moreover, the experimental literature is divided in what sense risk aversion can explain behavior in first-price auctions with independent private values (see Kagel, 1995). On the other hand, the "aggression" motive may not be present in the auction because subjects may view it more like an individual decision task.

A third reason could be that the effects are too small given the noise of the measures employed. There are at least two kinds of noise associated with the digit ratio as a measure of prenatal hormone levels. First, prenatal hormone levels may be correlated with the digit ratio but are certainly not perfectly correlated with the digit ratio. Second, there are inevitable measurement errors in measuring the length of the digits. Without using an x-ray, digit length must be measured from the crease in the skin where the finger meets the palm, but the bone meets the knuckle several millimeters below this crease. Thus, even if there is an effect of prenatal hormone levels on competitive bidding, we may not be able to find it with the digit ratio.

Finally, a fourth reason for our null finding could be that the biological factors at work are independent of 2D:4D. For instance, using a subsample of the current study, Schipper (2011a) reports results on bidding and profits in first-price auctions and salivary testosterone, estradiol, progesterone, and cortisol. He finds a positive (resp. negative) correlation between bidding (resp. profits) for progesterone only. It is known that salivary progesterone is uncorrelated with 2D:4D (McIntyre et al., 2007b) in naturally cycling women. Yet, in the same subsample of the current study, Schipper (2011b) observes that risk-taking in a lottery task for gains is positively correlated with salivary testosterone in males but not in females. Moreover, risk-taking is marginally negatively correlated with salivary cortisol in females. Thus, we may conclude that the endocrinological factors affecting behavior in strategic games may differ from endocrinological factors affecting behavior in single-person lottery tasks. In particular, the endocrinological factors at work for bidding may be independent from 2D:4D.

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.

In the 2010 wave of the experiment, we collect additional demographic information on sex life, life-style, dietary preferences etc. not used in this study. Some of this information is used in Schipper (2011a, b).

B Results on Interaction Terms

Table 8: Interaction of the Digit Ratio and Low Values

	(full)	(female)	(male)	(asian)	(asian-female)	(asian-male)	(white)	(white-female)	(white-male)
Digit Ratio	7.4738	9.6866	7.4760	21.8465*	13.1054	32.0068**	-21.9603**	-13.3383	-25.2902
	(7.7692)	(12.9215)	(7.8308)	(12.1391)	(19.9414)	(12.9051)	(10.0684)	(14.6604)	(15.1411)
Digit Ratio and Low Values	-0.0081	-0.5313	0.5598	0.1016	-0.3321	0.5279	0.2280	0.5983	0.1688
	(0.4701)	(0.8104)	(0.5433)	(0.5821)	(1.0334)	(0.7404)	(0.6847)	(1.1066)	(0.7463)
Observations	12000	5610	6390	6840	3690	3150	4020	1440	2580
R^2	0.8510	0.8511	0.8567	0.8381	0.8440	0.8430	0.8844	0.8836	0.8900

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

Table 9: Interaction of the Digit Ratio and Late Bids

	(full)	(female)	(male)	(asian)	(asian-female)	(asian-male)	(white)	(white-female)	(white-male)
Digit Ratio	4.5002	10.7460	1.0912	21.1767*	18.2936	24.8705*	-26.8339***	-11.8801	-32.7001**
	(7.8816)	(14.1770)	(7.6713)	(12.5625)	(21.4659)	(12.8698)	(8.8495)	(14.8312)	(13.1648)
Digit Ratio and Late Bids	5.9374	-2.7813	13.4986**	1.4837	-10.8532	14.9955	9.9664	-2.4942	15.0437
	(5.1728)	(9.1726)	(6.4370)	(7.1319)	(11.8658)	(10.5076)	(10.7273)	(16.0561)	(12.1672)
Observations	12000	5610	6390	6840	3690	3150	4020	1440	2580
R^2	0.8510	0.8511	0.8567	0.8381	0.8440	0.8431	0.8844	0.8836	0.8901

Standard errors (clustered at the session level) in parentheses. Significance levels: * 10%; ** 5%; *** 1%. We suppress from the report coefficients for num. of siblings, mathematics, science & engin., economics, social science, humanities, the dummy for the 2010 sample as well as the qubic polynomial in value and period indicators (bids), and the mean, standard deviation, and skewness of the empirical distribution of values (profits).

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