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DOI
10.1016/j.geb.2012.07.006

Publication date
2012

Document Version
Final published version

Published in
Games and Economic Behavior

Games and Economic Behavior 76 (2012) 457–470

Contents lists available at SciVerse ScienceDirect

Games and Economic Behavior

www.elsevier.com/locate/geb

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ARTICLE INFO

Article history:
Received 12 April 2011
Available online 25 July 2012

JEL classification:
A13
C91
D87

Keywords:
2D:4D
Menstrual cycle
Endocrinological economics
Trust
Altruism
Reciprocity
Lab experiment

ABSTRACT

We examine whether social preferences are partially determined by biological factors. We do this by investigating whether digit ratios (2D:4D) and menstrual cycle information are correlated with choices in ultimatum, trust, public good and dictator games. Digit ratios are thought to be a proxy for prenatal testosterone and oestrogen exposure and the menstrual cycle is a proxy for contemporary variations in a range of hormones. We find that digit ratios predict giving in all games. In our preferred specification, giving in the trust and public good games as well as reciprocity in the trust and ultimatum games vary significantly over the menstrual cycle. We discuss possible mechanisms behind these effects and conclude that biological factors play an important role in shaping social preferences.

1. Introduction

There is a large literature showing that levels of altruism, trust and reciprocity vary strongly across individuals. While we know that culture plays a role,[1] it is unclear whether nature too plays a part in forming these differences. In this paper, we analyse the correlation between behaviour in social preference games and physical proxies for biological factors. In particular, we use the second-to-fourth digit ratio, which is thought to be a marker for prenatal hormone exposure, and menstrual cycle information, which is a proxy for current fluctuations in a range of hormones and other biological processes. We argue that a significant correlation between these markers and economic choices in social situations would suggest that biological factors play a role in shaping social preferences.

The second-to-fourth digit length ratio (2D:4D), the ratio of the length of the index finger to the length of the ring finger, is established in utero and is frequently used as a proxy for prenatal exposure to testosterone and oestrogen which in turn is thought to have a crucial impact on brain development (Hines, 2011). The higher the exposure to testosterone and the lower the exposure to oestrogen, the longer the length of the ring finger relative to the index finger, which leads to a lower 2D:4D. The literature supporting these links is summarised in Section 2.1. Millet (2011) summarises the economic literature, which mainly emphasises 2D:4D as a proxy for the relative strength of prenatal testosterone exposure. This literature has

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[1] Oosterbeek et al. (2004), Henrich et al. (2001), Gächter et al. (2010), Herrmann et al. (2008).

0899-8256/$ – see front matter
http://dx.doi.org/10.1016/j.geb.2012.07.006

focused mainly on risk preferences, finding mixed results.[2] But there is a small number of studies looking at behaviour in social preference games, finding a negative correlation of 2D:4D with rejection rates in the ultimatum game in an all-male sample (van den Bergh and Dewitte, 2006) and a negative correlation with giving in the dictator game (Millet and Dewitte, 2006).[3] Sanchez-Pages and Turiegano (2010) find a non-monotonic effect of 2D:4D in a prisoner's dilemma whereby subjects with intermediary finger ratios are most likely to cooperate.

The menstrual cycle is characterised by predictable variations in the levels of a range of hormones, as well as other physiological mechanisms such as body temperature. These are described in detail in Section 2.2. While this is the first study looking at the correlation between the menstrual cycle and social preferences, a number of previous studies in economics have used the menstrual cycle as a proxy for hormonal fluctuations. Chen et al. (2009) and Pearson and Schipper (2012) find that bidding in first price auctions fluctuates over the cycle. Buser (2012) and Wozniak et al. (2010) find cycle effects for competitiveness, a trait which in turn has been found to be related to inequality aversion (Bartling et al., 2009).

A number of studies have also found links between specific hormones and social preferences. A series of placebo controlled studies demonstrates that oxytocin induces higher offers in the trust game (Kosfeld et al., 2005; Baumgartner et al., 2008) and increases generosity in the ultimatum game (Zak et al., 2007). Endogenous oxytocin, stimulated through massage and receiving money in a trust game, increases reciprocity (Morhenn et al., 2008). Burnham (2007) detects a positive correlation between current testosterone levels and rejections in the ultimatum game and Zak et al. (2009), in a placebo controlled study, find testosterone to cause both lower offers and more rejections in men. Conversely, Eisenegger et al. (2010) find that testosterone increases ultimatum offers in women. Randomly treating a sample of post-menopausal women with oestrogen and testosterone, Zethraeus et al. (2009), on the other hand, find no impact on altruism, trust or fairness.[4]

We conduct a laboratory experiment on social preferences and collect information on menstrual cycles, contraceptive use, and 2D:4D through a post-experimental questionnaire. This paper contributes to the literature in several ways. We are the first to investigate the correlation between 2D:4D and trust and positive reciprocity. Compared to previous investigations on 2D:4D and other social preferences, our study features a larger range of games and a much larger sample size. This study is also the first to investigate the impact of the menstrual cycle on social preferences, using a range of social preference games covering trust, altruism, and positive as well as negative reciprocity.

We find that digit ratios are strongly and significantly correlated with choices in the social preference games. Subjects with a lower digit ratio give less in all four games. We find at least some evidence that giving in the trust, public good and dictator games, and reciprocity in the trust and ultimatum games vary over the menstrual cycle. The results are most robust for giving and reciprocating in the trust game. These findings are consistent with the hypothesis that social preferences are partially biologically predetermined and are influenced by contemporary biological processes.

Section 2 gives details on our biological markers. Section 3 describes the data and Section 4 explains the experimental design. Section 5 describes the results and Section 6 discusses possible mechanisms. Section 7 concludes.

2. Biological markers

2.1. 2D:4D

The ratio of the length of the index finger to the length of the ring finger (2D:4D), which is established in utero, has been used extensively as a marker for the strength of prenatal hormone exposure (see Manning, 2002, for an introduction). Outside of economics, 2D:4D has been found to be correlated with many traits including reproductive success (Manning et al., 2000), sexual orientation (Robinson and Manning, 2000) and competitiveness in sports (Manning and Taylor, 2001).[5] 2D:4D is thought to be negatively correlated with testosterone exposure — the stronger the exposure, the shorter the index finger relative to the ring finger — and positively with oestrogen exposure in utero. It is reliably higher in women, at least in samples of white individuals. Some studies have also pointed towards a correlation between 2D:4D and current hormone concentrations in adults (Manning et al., 1998) but a meta study (Hönekopp et al., 2007) concludes that there is no significant link. However, lower 2D:4D has also been associated with higher sensitivity to the effects of testosterone

[2] See Dreber and Hoffman (2007), Apicella et al. (2008), Sapienza et al. (2009), Garbarino et al. (2011), Schipper (2011a), Branas-Garza and Rustichini (2011) and Coates et al. (2009). Also see Pearson and Schipper (2011) on bidding in auctions and Kastlunger et al. (2010) on tax compliance in a laboratory game, both of whom fail to find significant effects of 2D:4D.

[3] However, van den Bergh and Dewitte (2006) find that exposure to sexually stimulating photographs reverses the relationship between 2D:4D and rejections in the ultimatum game and Millet and Dewitte (2009) find that exposure to aggression cues reverses the relationship between 2D:4D and giving in the dictator game.

[4] A number of further studies have investigated the link between biological factors and social preferences using other approaches. Comparing the behaviour of monozygotic and dizygotic twins, a series of studies demonstrates that giving and reciprocity in the trust game (Cesarini et al., 2008), responder behaviour in the ultimatum game (Wallace et al., 2007), and generosity in the dictator game (Cesarini et al., 2009) are partly hereditary. Yet another strand of the literature has found links between specific genes and behaviour in the dictator game (Knafo et al., 2008; Israel et al., 2009). Finally, Buser (2010) finds significant correlations between handedness and choices in the trust, ultimatum, and dictator games.

[5] See Putz et al. (2004) for a summary of sexually dimorphic traits which have been found to correlate with 2D:4D. In a replication, the authors fail to reproduce most of them.

(Manning et al., 2003). Higher sensitivity to testosterone amplifies the effects of prenatal testosterone but may also mean that adults with lower 2D:4D are more affected by current hormone levels.

The most direct evidence for the link between 2D:4D and prenatal hormone exposure comes from Lutchmaya et al. (2004) who measure foetal oestrogen and testosterone levels before birth and record digit lengths at age two. They find that the right-hand digit ratio is significantly correlated with prenatal testosterone levels and the ratio of testosterone to oestrogen levels. Earlier studies show that individuals with conditions associated with very high prenatal testosterone levels exhibit significantly smaller 2D:4D (Brown et al., 2002).[6] 2D:4D is determined before birth and thus before economic, social, or cultural factors could shape social preferences.

We collect 2D:4D information through a post-experimental questionnaire by asking subjects the following questions: "On your left (right) hand, which finger is longer: the index finger or the ring finger?" (the possible answers are "index finger", "ring finger", and "equal length"). While this measure is less precise than, for example, hand scans it has a number of advantages. It can be easily included in any questionnaire and is less intrusive on the privacy of subjects. In order for this approach to be valid, there needs to be a strong correlation between the answers to these questions and finger ratios. We validated our measure by taking hand scans from 78 undergraduate students at the University of Amsterdam and asking them the same questions. The difference in average 2D:4D (as measured from the hand scans) between individuals indicating a longer ring finger on both hands, those indicating a longer index finger on both hands and those in between is highly significant ($p = 0.00$; Kruskal Wallis test).[7] The difference in 2D:4D between those indicating a longer ring finger on both hands and those indicating a longer index finger on both hands is equal to approximately 1.2 standard deviations.

A potential issue with using 2D:4D is that digit ratios and the effect of digit ratios on outcomes may vary between individuals of different race (Pearson and Schipper, 2012). We did not collect the race of our subjects but we collected nationality. In order to reduce noise and eliminate a potential confounding factor, we exclude non-European subjects from the sample we use in our digit ratio regressions. A further potential problem with our measure is that a subject's psychological state may influence the assessment of their own finger length. For example, if subjects are aware of gender differences in digit ratios, those who feel more masculine may be biased towards reporting a longer ring finger. We can directly address this question as in the post-experimental questionnaire, we asked subjects the following question: "On a scale from 1 (very feminine) to 6 (very masculine), how would you describe yourself?" This measure correlates highly with gender ($p = 0.00$; rank-sum test) but not with finger ratios or outcomes.[8] Moreover, in our validation sample we find very strong correlations between self-assessed and objectively measured digit ratios for both men and women separately.

2.2. The menstrual cycle

The medical literature commonly divides the menstrual cycle into five phases (see e.g. Richardson, 1992) across which the levels of several hormones fluctuate according to a predictable pattern. Assuming a menstrual cycle standardised to 28 days, we can distinguish the menstrual phase (days 1 to 5), the follicular phase (days 6 to 12), the ovulatory phase (days 13 to 15), the luteal phase (days 16 to 23), and the premenstrual phase (days 24 to 28). The levels of oestrogen, progesterone, the luteinising hormone (LH), and the follicle-stimulating hormone (FSH) all fluctuate over the cycle (see Fig. 1). Blood levels of oxytocin have also been shown to vary over the menstrual cycle with a peak during the follicular and ovulatory phases (Salonia et al., 2005; Altemus et al., 2001). Testosterone concentration also varies over the cycle, experiencing a mid-cycle peak which coincides with the peak in FSH and LU concentrations (Bloch et al., 1998). Finally, body temperature also varies over the cycle experiencing a sharp increase during ovulation.

We allocate subjects experiencing a natural menstrual cycle to one of the five menstrual cycle phases based on the cycle information collected through our post-experimental questionnaire. We solicited detailed menstrual cycle information including the beginning of the last menstruation, average cycle length, current menstrual bleeding and regularity of the cycle. Most of the variability in cycle length between individuals stems from differences in the length of the follicular phase. The length of the ovulatory, luteal, and premenstrual phases on the other hand is similar across individuals (Hampson and Young, 2008). We therefore adjust the length of the follicular phase to account for differences in cycle length between subjects.[9] We further reduce misallocations by only allocating subjects to the menstrual phase who indicate to be currently experiencing menstrual bleeding.

Using self-reported menstrual cycle data nevertheless introduces measurement error. Women often misestimate their cycle length (Small et al., 2007) and cycle length tends to vary around the mean over time (Creinin et al., 2004). Moreover, while the follicular phase varies most with the length of the cycle, there is some variability in the length of other phases too (Stern and McClintock, 1998). As women estimate their cycle length correctly on average (Creinin et al., 2004), this

[6] See Lutchmaya et al. (2004) for a summary of further indirect evidence for the link between prenatal testosterone and 2D:4D.

[7] The measure is also significant for the right and left hands individually ($p = 0.00$ and $p = 0.01$) and for men and women separately ($p = 0.05$ and $p = 0.01$). The sample of 78 students consisted of 33 men and 45 women.

[8] A regression of a ring-finger dummy (indicating the subject reported a longer ring finger on both hands) on self-rated masculinity yields a parameter estimate of 0.036 (s.e. 0.081) for men and −0.036 (0.046) for women. An analogue regression for index fingers yields parameter estimates of −0.007 (0.064) for men and 0.010 (0.047) for women. We also regressed self-rated masculinity on choices in our games using the same set of controls as in Section 5. The coefficient is never significant which further confirms that a bias in reported finger ratios due to self-perceived masculinity cannot explain our results.

[9] This method is taken from Pearson and Schipper (2012).

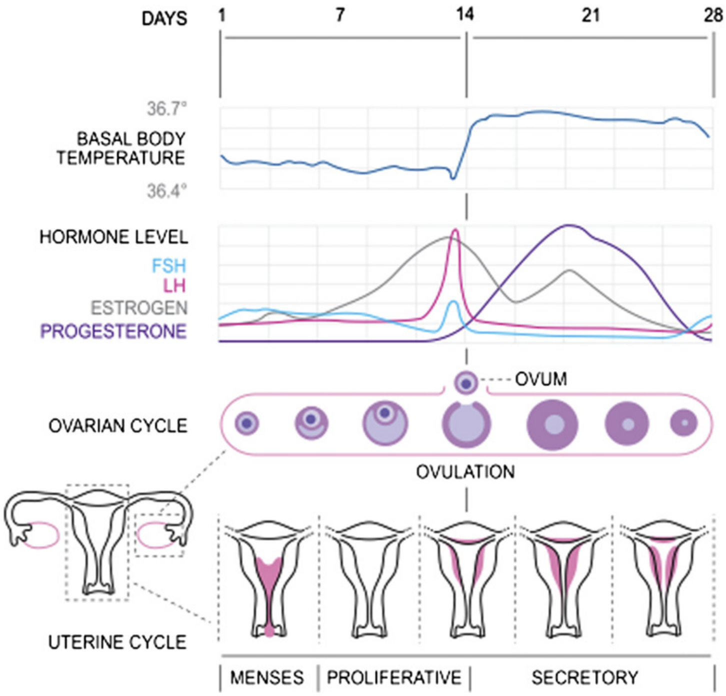

Fig. 1. Hormone levels over the menstrual cycle. http://en.wikipedia.org/wiki/File:MenstrualCycle2_en.svg.

leads to random misallocations.[10] To check whether our results are robust to our adjustment of menstrual cycle phases, we also report p-values for two alternative specifications: one where we account for cycle length by adjusting the length of all cycle phases proportionally (universally adjusted phases) and one where we do not adjust phase length at all (unadjusted phases). As a further robustness check, we conduct all our analyses on the subsample of regularly cycling women as well.

Compared to placebo controlled studies on individual hormones, it is difficult to pinpoint precise mechanisms using menstrual cycle information. But contrary to exogenously induced hormone shocks the menstrual cycle occurs naturally and constantly, making the estimated effects especially relevant as predictors of choices in social situations. Moreover, the women in our sample have years of experience with the hormonal fluctuations brought about by the menstrual cycle and therefore a lot of time to adapt to them. An impact of the menstrual cycle on social preferences would therefore constitute strong evidence of an impact of biological factors.

2.3. Hormonal contraceptives

In women using hormonal contraceptives such as the pill, vaginal rings or contraceptive patches, which contain varying levels of artificial oestrogen and progestins,[11] hormonal fluctuations are different. These contraceptives have in common that they are subject to a 28-day cycle wherein a 21-day intake period, which is characterised by constant daily hormone doses, is followed by a 7-day break during which hormone intake levels drop to zero.[12] Oestrogen excretion by the body is markedly reduced in women taking hormonal contraceptives and progesterone excretion ceases almost completely (Rivera et al., 1999). This leads to a regular pattern whereby levels of artificial oestrogen and progestin are high during the 21-day intake period and low during the 7-day pill break. Oxytocin levels do not vary over the cycle for contraceptive takers (Salonia et al., 2005).

We use our post-experimental questionnaire to ask a series of detailed questions concerning the use of hormonal contraceptives, including the kind of contraceptive and the number of days into the current pill packet or the current pill-break.[13] This allows us to construct a binary variable indicating whether a subject currently has high or low hormone levels. The female subjects in our sample take many different oral contraceptives. By comparing subjects on the pill break with those taking the pill, we measure the effect of the average contraceptive. It might seem attractive to use the information on

[10] Creinin et al.'s (2004) subject pool consists of women reporting a regular menstrual cycle. We also ask subjects whether their cycle is regular and estimate all our regressions also on the sub-sample of regularly cycling subjects.

[11] A progestin is a synthetic hormone that has effects similar to progesterone.

[12] For some contraceptives, the length of the intake phase and break may be slightly different (e.g. 24/4).

[13] Three subjects stated using hormonal contraceptive rings which are placed in the vagina for 21 days followed by a break of 7 days. We asked those subjects how many days ago they applied the ring they are currently using or how many days they are into the current break.

Table 1
Lab sample characteristics.

	Sample	Women	Men
N	252	157	95
2× ring finger longer	99	52	47
2× index finger longer	78	60	18
ring finger longer (right)	119	65	54
index finger longer (right)	96	70	26
ring finger longer (left)	121	63	58
index finger longer (left)	97	73	24
Age	22.13	22.02	22.32
Nationality (in %):			
Dutch	71.83	68.79	76.84
Western Europe	3.97	4.46	3.16
Eastern Europe	11.90	13.38	9.47
Asia	8.73	11.46	4.21
America	2.38	1.91	3.16
Other	1.19	0	3.16

Table 2
Digit ratio distribution for European subjects.

Left 2D:4D	Right 2D:4D			Total
	Longer index	Equal length	Longer ring	
Longer index	67	7	11	85
Equal length	7	15	7	29
Longer ring	9	12	86	107
Total	83	34	104	221

Table 3
Subjects by menstrual cycle phase.

Menstrual cycle or pill cycle phase	All subjects	Regular cyclers
Menstrual phase	17	10
Follicular phase	31	17
Ovulatory phase	8	6
Luteal phase	9	8
Premenstrual phase	16	10
Total	81	51
Pill break (7 days)	24	
Pill intake phase (21 days)	47	
Total	71	

oestrogen dosage and progestin content of the oral contraceptives to disentangle effects. But the exact contraceptive brand prescribed to an individual — and therefore the oestrogen and progestin dosage — is likely correlated with many things including baseline hormone levels and is possibly endogenous with respect to the outcome variables. For the same reason, one cannot derive causal effects from a comparison of pill-takers and naturally cycling women.

3. Data

Table 1 contains descriptive statistics. As expected, men are significantly more likely to indicate a longer ring finger on both hands (Wilcoxon rank-sum test; $p = 0.01$) while women are significantly more likely to indicate a longer index finger ($p = 0.00$).[14] Table 2 shows the sample distribution of digit lengths for European subjects ($N = 221$). 86 subjects have a longer ring finger and 67 have a longer index finger on both hands, with the remaining 68 subjects having mixed ratios.

Table 3 shows the distribution of female subjects across menstrual cycle phases. Five subjects indicated using implanted contraceptive devices (IUD) which completely suppress menstruation and are therefore excluded from the analysis based on cycle phases. Of the remaining 152 female subjects, 81 do not take hormonal contraceptives and therefore experience a natural cycle. When including subjects whose cycle length is irregular, menstrual phase and follicular phase subjects seem

[14] This also applies to the right and left hand separately. Gender difference p-values for ring and index finger lengths are 0.018 and 0.007 respectively for the right hand and 0.001 and 0.001 respectively for the left hand.

overrepresented. As mentioned above, the follicular phase is the most variable in length and our algorithm therefore adjusts the length of the follicular phase accordingly. Women who experience an irregular cycle — and whose average cycle length is therefore a bad predictor of the current cycle — report cycles that are 3.9 days longer on average ($p = 0.00$) and are therefore more likely to be allocated to the follicular phase. Also, irregularly cycling women may experience intermittent menstrual bleeding and be falsely assigned to the menstrual phase. Indeed we find that 21 out of 30 irregularly cycling women are assigned to phase 1 or 2.[15]

4. Experimental design

The experiment consists of four social preference games which have been widely used in the literature: an ultimatum game, a trust game, a public good game, and a dictator game. Overall, the experiment lasted for seven rounds and one of the rounds was randomly picked for payment at the end of the experiment. Subjects also received a show-up fee of €10. We ran a total of twelve sessions in December 2009 and January 2010, all of which were conducted in the computer laboratory of the Center for Research in Experimental Economics and Political Decision-Making (CREED) at the University of Amsterdam. The subjects were recruited through CREED's online recruitment system whereby more slots were allocated to female participants to ensure a large enough sample for the analysis of menstrual cycle effects. The experiment was programmed and conducted with the software z-Tree (Fischbacher, 2007). The sessions lasted for approximately two hours and average earnings were around €21.[16]

In the ultimatum game (Güth et al., 1982), the Proposer receives an endowment of €20 while the Responder starts out with nothing. The Proposer decides how much to send to the Responder who can then decide whether to accept or reject the proposal. In case of rejection, both players receive zero, so that the subgame-perfect Nash equilibrium predicts that all positive offers are accepted and Proposers should thus send the lowest possible amount. Again, there is a large literature showing that Proposers send positive amounts, usually in the range between 25 and 50 percent of their endowment, and that Responders are willing to forfeit money by rejecting low offers (Roth, 1995).

In the trust game (Berg et al., 1995), two subjects are paired up and each receives an endowment of €10. The first mover (the "Proposer") can then decide how much of his endowment he wishes to send to the second mover (the "Responder"). The amount sent is tripled and the Responder can then decide how much of the money, including his endowment, to send back to the Proposer. Because the Responder has no financial incentive to send back anything, the subgame-perfect Nash equilibrium predicts that the Proposer will not send any money. In the social optimum, on the other hand, the Proposer would send his entire endowment of €10 and the Responder would return less than €30 and more than €10, leaving both parties better off. There is a large literature showing that Proposers send on average around 50 percent of their endowment and that Responders reciprocate by returning on average nearly 50 percent of the received transfer (Levitt and List, 2007).

The public good game is a generalisation of the prisoner's dilemma game whereby subjects are matched in groups of four and are each endowed with €15. They can then decide how much of the endowment to keep and how much to give to the group. Each Euro given to the group is doubled and split equally amongst the group members such that each Euro given to the group pays 50 Cents to each group member. The social optimum is for all the players to invest everything, but as each player has an incentive to free-ride, the Nash equilibrium predicts zero contributions. There is a large literature reporting substantial positive contributions, usually around 50 percent of the initial endowment in a one-shot setting (Ledyard, 1995).

Finally, we implemented a binary version of the dictator game. In the dictator game, the Proposer again receives an endowment of €20 and has to pick between two options: splitting the pot equally with the Responder (who receives no endowment) or keeping €18 while giving only €2 to the Responder. The Responder has no possibility to reciprocate and the game is consequently a good tool for measuring altruism. The Nash equilibrium of course predicts that the Proposer sends the smallest amount possible, but a large literature finds that when able to decide freely, over 60 percent of subjects send a positive amount (Roth, 1995).

The experiment lasted for seven rounds: two rounds of the ultimatum game, two rounds of the trust game, one round of the public good game, and two rounds of the dictator game (in this order). In all games, only discrete amounts of money could be chosen. For the ultimatum, trust and dictator games each subject played each role exactly once. Subjects were rematched after each round, with the rematching occurring within clusters of eight subjects, and were paired with a different subject in each round.[17] The observations are consequently divided into 34 independent clusters.[18] We take this into account by using clustered standard errors in all regressions.

The fact that all subjects played both roles in each game and played all games in the same order can lead to order effects and experience effects within and between games. The nature of the games makes it impossible to give no feedback

[15] Menstrual cycle details are sensitive information to ask and a female assistant was therefore present at all sessions and was responsible for all interactions with the subjects concerning the post-experimental questionnaire. In the end, selective non-response turned out not to be a problem as all subjects chose to answer the questions.

[16] The data from this experiment has also been used by Buser (2010), who finds that left-handed men give more in the trust and ultimatum games, are more reciprocal in the trust game, and are less likely to reject offers in the ultimatum game. Left-handed women are less generous in the dictator game.

[17] With the exception of the public good game which uses groups of four players and in which subjects were matched with at least some players with whom they had previously interacted.

[18] In 5 out of 12 sessions, the number of subjects was not divisible by 8 which leads to 5 clusters which only contain 4 subjects.

at all and we opted for giving full feedback after every round. Learning from experience could conceivably be correlated with finger ratios or menstrual cycle phases.[19] Despite the feedback, however, we expect learning to be limited. Subjects are randomly allocated to clusters and rematched across rounds and consequently interact with a new partner in a new game in each round. The behaviour of another subject in a previous round is therefore a very noisy signal of what to expect in a later round in a different game with a different subject. We therefore assume the effects of experience in previous rounds to be orthogonal to the estimated finger ratio and menstrual cycle effects. To further ensure that our results are not due to order effects or past experience, we control for a first mover dummy and past experience in all regressions. This means that in all our regressions, we include controls for the play of opponents in all previous rounds.

5. Results

In all following regression tables, the dependent variables are the initial offer in the ultimatum game and a rejection dummy for ultimatum responders in Columns 1 and 2, the initial offer and the proportion returned in the trust game in Columns 3 and 4,[20] the contribution to the public good in Column 5, and a binary indicator for choosing the selfish allocation in the dictator game in Column 6. The regressions in Columns 2 and 4, which deal with responder behaviour, control for the amount received from the proposer. Additionally, we control for age and nationality in all regressions.[21] To control for learning and experience effects, standard errors are clustered as described in Section 4 and we control for experience in previous rounds in all regressions.

5.1. 2D:4D

Table 4 shows results for regressions of choices in the experimental games on digit ratio indicators for the subsample of European subjects.[22] The first three regressions compare subjects for whom their ring finger is longer than their index finger (low 2D:4D individuals) to the rest of the sample. The rest of the regressions split the sample into three groups, using dummies for a longer ring finger (low 2D:4D) and a longer index finger (high 2D:4D). Subjects with fingers of equal length (intermediate 2D:4D) are therefore the reference group.[23] Table 5 summarises the results from these regressions and reports *p*-values for joint significance of digit ratio dummies. All regressions control for gender to avoid that the finger ratio coefficients simply pick up gender effects. The 2D:4D coefficients therefore give the average effect for the whole sample conditional on gender. Also, qualitative results are the same for both genders separately.[24]

The first specification in Table 4 shows that subjects with a longer ring finger on both hands give significantly less than the rest of the sample in the trust, ultimatum, public good and dictator games.[25] Hence, 2D:4D is positively correlated with giving rates in all games. The second specification shows that when using the right-hand ratio only (which is the one most commonly used in the literature), subjects with a longer ring finger also return a significantly lower proportion in the trust game but the coefficient on giving in the ultimatum game is now marginally insignificant ($p = 0.12$). All effects go in the same direction when using the left-hand ratio only in the third specification but only trust and ultimatum game giving, as well as trust game reciprocity, remain significant. However, the left-hand ratio is rarely used in the literature and is seen as a less reliable and more noisy predictor of prenatal hormone exposure (see for example Lutchmaya et al., 2004). Rejection rates in the ultimatum game are never significantly correlated with 2D:4D. Our finding of a positive correlation between 2D:4D and giving in the dictator game contradicts the findings of Millet and Dewitte (2006).[26]

In the last three specifications, we split the sample into three groups by also adding an index finger dummy. The coefficients therefore now indicate the difference between subjects with a longer ring (or index) finger and subjects for whom ring and index finger have equal length. To determine whether 2D:4D has a significant impact in these regressions, we test for the joint significance of the two finger ratio dummies. The results of these tests are reported in Table 5. Most of the results are unaffected — i.e. those with longer ring fingers are less generous than the middle group and those with longer index fingers are more generous. But for the public good game we obtain non-monotonic effects which are significant for the right hand only: subjects with longer ring fingers and subjects with longer index fingers are both less generous than those whose index and ring fingers are of equal length. This is consistent with Sanchez-Pages and Turiegano (2010) who

[19] For example, Branas-Garza and Rustichini (2011) find 2D:4D to be correlated with cognitive ability.

[20] The proportion returned is calculated including the €10 endowment of the responder.

[21] Results without these controls are very similar and are therefore not reported.

[22] Results are very similar when using the whole subject pool.

[23] In the first specification, which uses both hands, the reference group is made up of people who do not have a longer ring or longer index finger on both hands.

[24] The only exceptions are rejection in the ultimatum game, where men with a lower 2D:4D are insignificantly less likely to reject and women with a lower 2D:4D are insignificantly more likely to reject, and contributions to the public good, where women show the same positive correlation of 2D:4D with contributions as the men for the right-hand ratio and the double ratio, but a zero correlation for the left-hand ratio.

[25] Throughout the paper, we take $p < 0.10$ to represent statistical significance.

[26] The ring finger coefficient for ultimatum rejections is positive, if not significant, which is in accordance with van den Bergh and Dewitte (2006) who find that 2D:4D is negatively correlated with rejection rates.

Table 4
Digit ratios (2D:4D) and social preferences.

	(1) Ultimatum offer	(2) Ultimatum rejection	(3) Trust offer	(4) Proportion returned	(5) Public good contribution	(6) Selfish dictator
Longer ring (left and right)	−1.008** (0.414)	0.029 (0.044)	−1.014** (0.395)	−0.019 (0.013)	−1.101* (0.593)	0.076** (0.035)
Longer ring (right)	−0.719 (0.450)	0.021 (0.047)	−0.869** (0.397)	−0.038*** (0.012)	−1.504** (0.556)	0.094** (0.039)
Longer ring (left)	−1.106** (0.412)	0.016 (0.039)	−0.968** (0.406)	−0.028* (0.015)	−0.767 (0.621)	0.038 (0.040)
Longer index (left and right)	0.118 (0.596)	0.025 (0.047)	0.463 (0.549)	0.025 (0.021)	0.111 (0.815)	0.035 (0.059)
Longer ring (left and right)	−0.952** (0.411)	0.041 (0.046)	−0.793 (0.497)	−0.007 (0.016)	−1.048 (0.748)	0.093** (0.044)
Longer index (right)	−0.266 (0.584)	0.035 (0.056)	−0.171 (0.485)	−0.004 (0.023)	−1.096 (0.812)	0.019 (0.066)
Longer ring (right)	−0.906* (0.476)	0.045 (0.063)	−0.989* (0.501)	−0.040** (0.018)	−2.273*** (0.777)	0.108* (0.060)
Longer index (left)	0.314 (0.672)	0.060 (0.058)	0.564 (0.560)	−0.008 (0.028)	−0.194 (1.128)	0.023 (0.054)
Longer ring (left)	−0.879 (0.592)	0.060 (0.057)	−0.562 (0.602)	−0.033 (0.023)	−0.907 (1.056)	0.055 (0.051)
N	221	221	221	221	221	221
Mean	7.973	0.136	4.172	0.117	6.507	0.878
SD	(3.171)	(0.343)	(3.143)	(0.141)	(4.890)	(0.328)
Controls	yes	yes	yes	yes	yes	yes
Offer received	no	yes	no	yes	no	no
Scale	0–20	binary	0–10	0–1	0–15	binary

All coefficients are from OLS regressions. The dependent variables are the initial offer in the ultimatum game and a rejection dummy for ultimatum responders in Columns 1 and 2, the initial offer and the proportion returned in the trust game in Columns 3 and 4, the contribution to the public good in Column 5, and a binary indicator for choosing the selfish allocation in the dictator game in Column 6. Trust, ultimatum and public good game giving are expressed in Euros. Clustered standard errors in parentheses; $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. Controls consist of gender, age, nationality and experience in previous games; the regressions in Columns 2 and 4 additionally control for the offer received from the first mover. The regressions are estimated on the subsample of European subjects.

Table 5
Digit ratios (2D:4D) and social preferences: summary of regressions.

		(1) Double	(2) Right hand	(3) Left hand
Ultimatum offer	4D	+(0.02)**	+(0.12)	+(0.01)**
	2D:4D	+(0.05)**	∼(0.16)	+(0.04)**
Ultimatum rejection	4D	−(0.52)	−(0.66)	−(0.68)
	2D:4D	∼(0.66)	∼(0.76)	∼(0.54)
Trust offer	4D	+(0.015)**	+(0.04)**	+(0.02)**
	2D:4D	+(0.03)**	∼(0.10)*	+(0.04)**
Proportion returned	4D	+(0.16)	+(0.00)***	+(0.07)*
	2D:4D	+(0.20)	+(0.01)**	+(0.16)
Public good contribution	4D	+(0.07)*	+(0.01)**	+(0.23)
	2D:4D	∼(0.18)	∼(0.01)**	∼(0.47)
Selfish dictator	4D	−(0.03)**	−(0.02)**	−(0.34)
	2D:4D	∼(0.09)*	−(0.06)*	∼(0.53)

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$ (p-values in parentheses). + positive effect of 2D:4D (outcome positively correlated with length of index finger and negatively with length of ring finger), − negative effect of 2D:4D (outcome negatively correlated with length of index finger and positively with length of ring finger), ∼ non-monotonic effect of 2D:4D (ring and index finger coefficients have the same sign). 4D designates regressions splitting the sample in two groups (ring finger > index finger vs the rest) and 2D:4D designates regressions splitting the sample in three groups (ring finger < index finger, ring finger > index finger, and the rest). All significance levels are from Wald tests for (joint) significance of ring-finger and index-finger coefficients. See Table 4 for the regression coefficients.

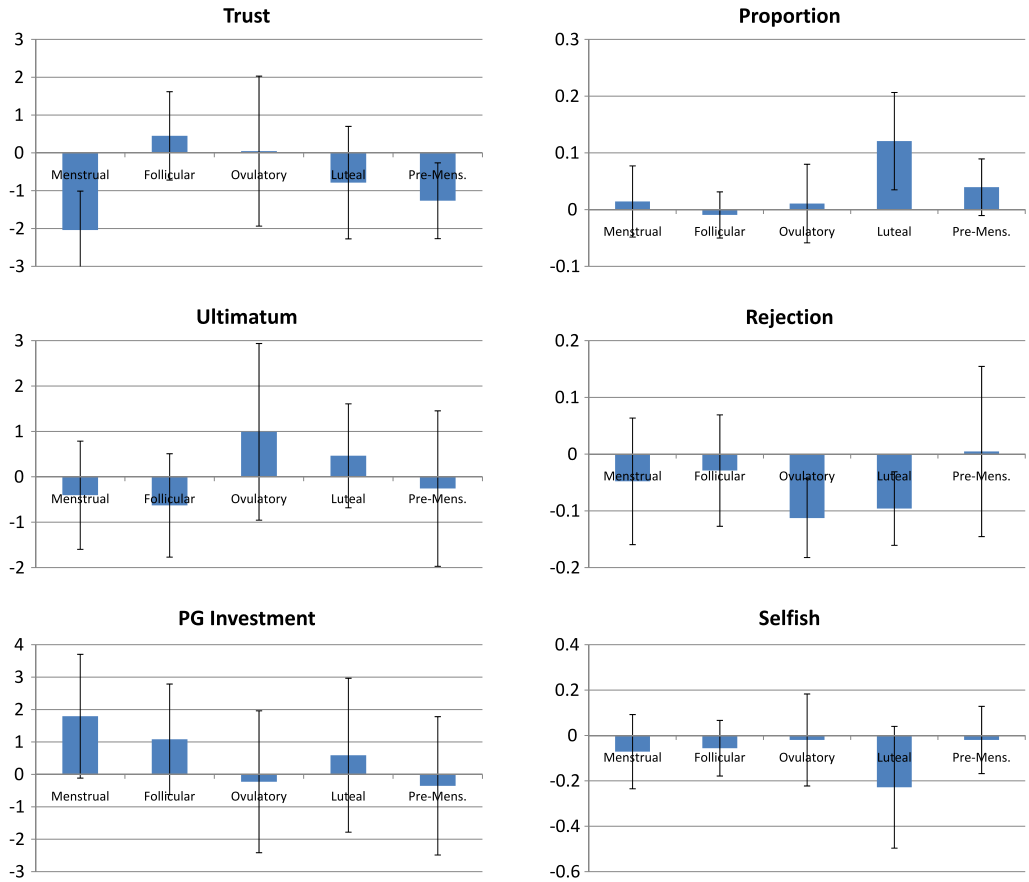

Fig. 2. The menstrual cycle and social preferences. Coefficients and 90%-confidence intervals are from OLS regressions using the subsample of regularly cycling women; the regressions on trust and ultimatum game reciprocity control for amounts received; effects are shown relative to the average choices of male subjects.

find that individuals with intermediate values of 2D:4D are more likely to cooperate in a prisoner's dilemma game than either low or high 2D:4D subjects.[27]

5.2. Menstrual cycle

The graphs in Fig. 2 show choices for female subjects in different phases of their menstrual cycle relative to the average choice of male subjects. Table 6 reports coefficients for regressions of menstrual cycle phase dummies on choices in all games (men being the reference group). Controls and clustering are as described at the start of Section 5. We report coefficients both for regressions using all naturally cycling female subjects and for regressions using only regularly cycling subjects. The regressions use follicular phase-adjusted menstrual cycles as described in Section 2.2.

The graphs in Fig. 2 show that women give significantly less than men in the trust game during the menstrual and pre-menstrual phases, but not during the middle part of their cycle. Ultimatum game giving also experiences a mid-cycle peak during the ovulatory phase but is never significantly different from the giving rates of men. The likelihood of rejecting ultimatum offers is lower during the ovulatory phase and the luteal phase. Giving in the dictator game and reciprocity in the trust game are highest during the luteal phase. Finally, giving in the public good game is highest during the menstrual phase.

The regression results in Table 6 allow us to test which of these fluctuations across the cycle are significant. In each column, we report *p*-values for a post-estimation test of equality of the five menstrual cycle dummies. The columns with uneven numbers report regressions using the whole sample and the columns with even numbers report regressions using only subjects experiencing a regular cycle. The coefficients on the menstrual cycle dummies represent the difference between the average choices of women in the respective phase and the average choices of men.

[27] Findings of non-monotonic effects of prenatal testosterone exposure are common; a further example is the impact of prenatal testosterone on homosexuality in men (Robinson and Manning, 2000).

Table 6
Menstrual cycle and social preferences.

	(1) Ultimatum	(2) Ultimatum	(3) Rejection	(4) Rejection	(5) Trust	(6) Trust	(7) Proportion	(8) Proportion	(9) PG	(10) PG	(11) Selfish	(12) Selfish
Menstrual	−0.070	1.405	−0.058	0.017	−1.578***	−1.600**	0.034	0.061	2.665*	3.995***	−0.102	−0.094
	(0.847)	(0.839)	(0.064)	(0.086)	(0.460)	(0.589)	(0.037)	(0.042)	(1.358)	(1.427)	(0.101)	(0.136)
Follicular	−0.389	0.431	−0.026	−0.082	0.353	−0.546	0.008	−0.031	1.118	0.779	−0.044	0.050
	(0.790)	(0.925)	(0.062)	(0.081)	(0.641)	(0.683)	(0.026)	(0.030)	(0.773)	(0.878)	(0.076)	(0.086)
Ovulatory	0.692	2.075*	−0.131**	−0.157**	0.494	0.309	0.009	0.009	−1.444	−1.226	0.094	0.138
	(1.282)	(1.175)	(0.061)	(0.077)	(1.085)	(1.464)	(0.041)	(0.048)	(0.957)	(1.172)	(0.137)	(0.202)
Luteal	0.727	1.226	−0.083	−0.070	−0.879	−0.956	0.134**	0.121*	0.875	0.673	−0.210	−0.258
	(0.920)	(0.781)	(0.060)	(0.084)	(0.805)	(0.938)	(0.053)	(0.065)	(1.194)	(1.114)	(0.153)	(0.165)
Pre-mens.	−0.096	1.699	0.045	−0.023	−0.578	−1.120*	0.077**	0.056	1.016	−0.113	−0.083	−0.097
	(1.039)	(1.110)	(0.099)	(0.106)	(0.514)	(0.550)	(0.034)	(0.040)	(1.215)	(1.148)	(0.101)	(0.157)
N	176	146	176	146	176	146	176	146	176	146	176	146
Joint significance:												
p-val.	0.72	0.80	0.08	0.52	0.08	0.46	0.10	0.16	0.03	0.06	0.36	0.16
p-val. universally adj.	0.77	0.31	0.35	0.11	0.01	0.26	0.02	0.10	0.38	0.09	0.01	0.00
p-val. unadjusted	0.93	0.00	0.29	0.47	0.06	0.00	0.12	0.00	0.37	0.00	0.00	0.09
Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Offer	no	no	yes	yes	no	no	yes	yes	no	no	no	no
Scale	0–20	0–20	binary	binary	0–10	0–10	0–1	0–1	0–15	0–15	binary	binary

All coefficients are from OLS regressions. The dependent variables are the initial offer in the ultimatum game and a rejection dummy for ultimatum responders in Columns 1 to 4, the initial offer and the proportion returned in the trust game in Columns 5 to 8, the contribution to the public good in Columns 9 and 10, and a binary indicator for choosing the selfish allocation in the dictator game in Columns 11 and 12. Trust, ultimatum and public good game giving are expressed in Euros. Clustered standard errors in parentheses; $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. Controls consist of age, nationality and experience in previous games; the regressions in Columns 3, 4, 7 and 8 additionally control for the offer received from the first mover. The sample consists of women experiencing a natural menstrual cycle and all men (the regressions in even-numbered columns restrict the sample to regular cyclers and men). Men are the reference category.

Table 7
Hormonal contraceptives and social preferences.

	(1) Ultimatum offer	(2) Ultimatum rejection	(3) Trust offer	(4) Proportion returned	(5) Public good contribution	(6) Selfish dictator
Pill break	0.194	−0.035	−0.111	−0.025	0.530	−0.008
	(1.092)	(0.100)	(0.949)	(0.023)	(1.389)	(0.070)
N	71	71	71	71	71	71
Mean	8.845	0.197	3.647	0.117	6.197	0.915
SD	3.500	0.401	2.747	0.134	4.496	0.280
Controls	yes	yes	yes	yes	yes	yes
Offer received	no	yes	no	yes	no	no
Scale	0–20	binary	0–10	0–1	0–15	binary

All coefficients are from OLS regressions. The dependent variables are the initial offer in the ultimatum game and a rejection dummy for ultimatum responders in Columns 1 and 2, the initial offer and the proportion returned in the trust game in Columns 3 and 4, the contribution to the public good in Column 5, and a binary indicator for choosing the selfish allocation in the dictator game in Column 6. Trust, ultimatum and public good game giving are expressed in Euros. Clustered standard errors in parentheses; $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. Controls consist of age, nationality and experience in previous games; the regressions in Columns 2 and 4 additionally control for the offer received from the first mover. The sample is restricted to female contraceptive takers.

The first row of p-values is based on the regressions shown in the table. We can see that when using all naturally cycling women (odd-numbered columns), the variations across the five menstrual cycle phases of trust and public good game giving, as well as the likelihood of rejecting ultimatum game offers, are significant. The variation in trust game reciprocity is marginally significant. We also report p-values using alternative specifications of the menstrual cycle phases as described in Section 2.2. Some of the conclusions change when using universally adjusted or unadjusted phases. Dictator game giving now varies significantly over the cycle but variations in ultimatum game rejections and contributions to the public good are not consistently significant when using these alternative specifications. When we restrict the sample to regularly cycling women only (even-numbered columns), the estimated effects are similar but standard errors increase due to the smaller sample size (51 female subjects). In summary, we find evidence for variations in social preferences across the menstrual cycle but the conclusions are not always robust to the way the menstrual cycle phases are specified. The variations in trust game giving and reciprocity (Columns 5 and 7) appear to be the most robust.

It is difficult to say what these menstrual cycle results predict for contraceptive takers. Many studies which find significant fluctuations of behaviour over the natural menstrual cycle find no effect for contraceptive takers.[28] Moreover, the artificial hormones contained in hormonal contraceptives are not identical to their natural counterparts oestrogen and progesterone. Each pill brand contains a different artificial progestin, some of which, apart from imitating the effects of natural progesterone, also have a list of strong side effects (Mansour, 2006). But Buser (2012) finds that the effects of hormonal contraceptives on competitiveness are consistent with the difference between the high progesterone luteal phase and the rest of the cycle.[29] This raises the possibility of an impact of hormonal contraceptives on social preferences. The regressions reported in Table 7 show that this is not the case. For none of the social preference games are the choices of subjects in the pill-break different from the choices of subjects who were taking contraceptives at the time of the experiment.

6. Discussion

We interpret our findings as providing evidence that individual differences in trust, reciprocity and altruism are partially determined by biological factors. Given that our markers proxy for many biological mechanisms, it is difficult to be sure about the exact mechanisms that lay behind our findings. Digit ratios are a proxy for prenatal exposure to both testosterone and oestrogen which in turn are thought to have a multitude of organisational[30] effects. Similarly, a variety of hormones and other biological factors vary over the menstrual cycle. In this section, we nevertheless briefly discuss possible mechanisms, an endeavour which necessarily remains speculative.

The organisational effects of testosterone and oestrogen exposure occur between weeks seven and twelve of pregnancy and the relative strength of exposure is thought to have a strong impact on preferences and behaviour later in life (see Hines, 2009 for an introduction). It is thought that hormones exert these permanent effects by altering neural structures although the exact mechanisms are still largely unidentified (Hines, 2011). Amongst many identified behavioural effects, prenatal testosterone exposure is thought to have a negative impact on empathy (Baron-Cohen et al., 2004). These differences are present already at birth (Lutchmaya and Baron-Cohen, 2002), and at four years of age children with higher exposure have significantly lower social skills and more restricted interests (Knickmeyer et al., 2005). Empathy has been shown to be positively correlated with giving in social preference games (Barraza and Zak, 2009). A link between prenatal testosterone

[28] See Bröder and Hohmann (2003) on risky behaviour, Penton-Voak et al. (1999) on preferences for male faces, Thornhill and Gangestad (1999) on preferences for male body odour, and Miller et al. (2007) on tips earned by lap dancers.

[29] Also, Schipper (2011b) finds that salivary progesterone levels are associated with higher (more competitive) auction bids.

[30] Hormones can have organisational effects as well as immediate effects. Organisational effects are permanent effects of hormones on the structure and functioning of the body and brain. The critical periods during which organisational effects mostly occur are foetal development and puberty.

exposure and empathy is therefore a potential mechanism behind our finding of a positive correlation of 2D:4D with social preferences. However, current testosterone levels in adults have also been associated with social preferences and adults with a lower 2D:4D may be more sensitive to the effects of testosterone (Manning et al., 2003). Although 2D:4D is not significantly correlated with testosterone levels in adults (Hönekopp et al., 2007), the increased sensitivity to testosterone in individuals with low 2D:4D is another potential explanation for our findings.

Trust game giving is highest in mid-cycle during the follicular and ovulatory phases. Blood levels of oxytocin, which has been frequently linked to choices in the trust game, also experience a peak during these phases. However, oxytocin in the blood stream does not permeate the blood-brain-barrier (Ermisch et al., 1985). The correlation is therefore more likely due to the same brain mechanisms that are responsible for the oxytocin release influencing trust game giving rather than to direct action of the oxytocin itself. Testosterone secretion also experiences a mid-cycle peak. But the only study we are aware of that tests the impact of testosterone on trust game giving (Zethraeus et al., 2009) does not find an effect and testosterone has been shown to decrease self-rated trust towards strangers (Bos et al., 2010). Eisenegger et al. (2010) find that testosterone increases ultimatum game giving in women which is consistent with testosterone explaining our finding of a (not statistically significant) mid-cycle peak. LH and FSH also peak in mid-cycle (also coinciding with an increase in body temperature) and it is therefore difficult to nail down the exact mechanism.

Buser (2012) finds that competitiveness is significantly lower during the luteal phase and is negatively correlated with expected progesterone levels.[31] Bartling et al. (2009) find a negative relationship between competitiveness and preferences for egalitarian choices (choices that reduce favourable or unfavourable payoff inequality). Proposers in the dictator and ultimatum games and responders in the trust game make their choices in situations which are characterised by favourable inequality. The proportion returned in the trust game and giving in the ultimatum game are higher and the likelihood of being selfish in the dictator game is lower during the luteal phase although the difference is not significant in the case of the dictator and ultimatum games.[32] Conversely, we do not find this effect for giving in the trust and public good games where endowments are equal. Progesterone peaks during the luteal phase and a positive effect of progesterone on inequality aversion is therefore a possible explanation for our findings. On the other hand, Buser (2012) finds hormonal contraceptives — which contain artificial progestins — to also have a negative impact on competitiveness whereas we do not find an effect of contraceptives in any game.

7. Conclusions

Our results demonstrate that biological factors, both prenatal and current, play an important role in shaping social preferences. Subjects with a lower 2D:4D are less trusting, less reciprocal and less altruistic. As 2D:4D is established before birth, this is evidence that social preferences are partially biologically predetermined. 2D:4D is, amongst other things, a proxy for prenatal exposure to testosterone which in turn has important organisational effects on the brain. Our results therefore suggest the possibility of a neural basis for social preferences.

For women who experience a natural menstrual cycle, trust, reciprocity and altruism vary across cycle phases. Trust is highest before and during ovulation when several hormones are peaking. Altruism in games characterised by favourable income inequality is highest during the luteal phase which is characterised by a peak in progesterone levels. This points to an increase in inequality aversion at that point of the cycle, possibly mediated by progesterone. However, we encounter zero findings for contraceptive takers. Also, not all of the estimated fluctuations over the cycle are robust to alternative specifications of the menstrual cycle phases and further research with larger sample sizes could confirm the robustness of our results. Nevertheless, the observed variations in social preferences over the cycle provide further evidence for a biological basis for social preferences, specifically pointing towards an impact of hormones.

The biological markers we use are imprecise devices but they have unique advantages. Our 2D:4D indicators are simple enough to be included in questionnaires which is impossible for hand scans and hormone assays, let alone for direct prenatal hormone measurements during pregnancy. Furthermore — contrary to exogenously induced hormone shocks — the menstrual cycle occurs naturally and constantly, making the estimated effects especially relevant for our understanding of choices in social situations. Our results fit well with the growing literature showing that the strong individual differences observed in a large number of social preference experiments are at least partially biologically determined.

Acknowledgments

I am indebted to Hessel Oosterbeek and Erik Plug for their advice and support. I thank Burkhard Schipper and two anonymous referees for their many valuable comments. I would also like to thank seminar participants at the University of Amsterdam and at the ESA World Meeting 2010 for their comments. I also thank Lygia Cesar for great research assistance in the lab. I gratefully acknowledge financial support from the University of Amsterdam through the Speerpunt Behavioural Economics and thank CREED for letting me use their lab.

[31] Note that the menstrual cycle information was measured in a different way (and the method for defining the cycle phases was therefore different) in Buser (2012).

[32] OLS regressions of outcomes on luteal phase dummy using sample of naturally cycling women and controlling for age and nationality. Proportion returned in the trust game: $p = 0.01$; ultimatum game offer: $p = 0.20$; likelihood of being selfish in dictator game: $p = 0.11$.

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