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Author for correspondence:
Pablo Brañas-Garza
e-mail: branasgarza@gmail.com

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Animal behaviour

Digit ratio (2D : 4D) and prosocial behaviour in economic games: no direct correlation with generosity, bargaining or trust-related behaviours

Pablo Brañas-Garza[1], Antonio M. Espín[2], Teresa García-Muñoz[3] and Jaromír Kovářík[4,5]

[1]Department of Economics, LoyolaBehLAB, Universidad Loyola Andalucía, Cordoba, Andalucia 14004, Spain
[2]Department of Social Anthropology, Universidad de Granada, Granada, Granada 18071, Spain
[3]Department of Quantitative Methods, Universidad de Granada, Granada 18071, Spain
[4]Department of Economics, Universidad del País Vasco (UPV/EHU), Bilbao, País Vasco, Spain
[5]CERGE-EI, Prague, Czech Republic

PB-G, 0000-0001-8456-6009; AME, 0000-0002-1174-0771; TG-M, 0000-0003-1778-254X; JK, 0000-0002-0436-929X

Prenatal exposure to sex hormones exerts organizational effects on the brain which have observable behavioural correlates in adult life. There are reasons to expect that social behaviours—fundamental for the evolutionary success of humans—might be related to biological factors such as prenatal sex hormone exposure. Nevertheless, the existing literature is inconclusive as to whether and how prenatal exposure to testosterone and oestrogen, proxied by the second-to-fourth digit ratio (2D : 4D), may predict non-selfish behaviour. Here, we investigate this question using economic experiments with real monetary stakes and analyse five different dimensions of social behaviour in a comparatively large sample of Caucasian participants ($n = 560$). For both males and females, our results show no robust association between right- or left-hand 2D : 4D and generosity, bargaining or trust-related behaviours. Moreover, no differences in behaviour were found according to sex. We conclude that there is no direct correlation between 2D : 4D and these social behaviours.

1. Introduction

Humans display various social behaviours, such as generosity, fairness, trust and reciprocity, each with its own social and bio-psychological underpinnings [1–4]. However, while our species shows distinctive behavioural patterns in the social domain compared to other taxa, there exists large individual heterogeneity. For example, some people are more generous, trustful or reciprocal than others. Although we know that some of the variation emanates from cultural differences [5–7], considerable heterogeneity still emerges within cultural groups. This study analyses the biological roots of individual differences in generosity, bargaining and trust-related behaviours. Indeed, many studies—without relying on any particular biological trait—suggest that social behaviour is heritable or genetically determined to some extent [2,8,9]. Similarly, different biological and genetic factors at certain times of development might determine predispositions towards different social behaviours [10–12]. The amount of hormones individuals are exposed to during prenatal development could be one such factor [13–15]. Fetal exposure to hormones such as androgens and cortisol is known to exert organizational effects on the human body and brain which may influence behaviour later in life [16–19]. Since hormonal levels are strongly influenced by genetics [20,21], this may be a channel for the intergenerational transmission of behaviour.

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Concerning social behaviour, sex hormones and androgens in particular have attracted considerable attention. Numerous studies have examined the behavioural correlates of circulating (endogenous or administered) testosterone levels [22–28]. We focus on the organizational effects of prenatal exposure to testosterone. More specifically, we explore the relationship between fetal testosterone exposure and social behaviour in economic experiments. Previous studies have typically used the second-to-fourth digit ratio (2D : 4D) as a putative marker of prenatal exposure to testosterone or, more precisely, of the relative *in utero* exposure to testosterone compared to oestradiol ([29]). Although direct evidence for the 2D : 4D-fetal sex hormones link only exists for mice [29], rats [30,31] and birds [32], there is large indirect evidence and the ratio is commonly accepted as a proxy of fetal hormone exposure (also) in humans (see [33,34] for evidence and arguments against this interpretation). The 2D : 4D is calculated such that lower ratios correspond to higher exposure to testosterone and lower exposure to oestrogen. Consequently, males tend to display lower 2D : 4D values than females [35,36]. Many studies, some using large samples, have analysed the association between 2D : 4D and diverse aspects of social involvement and interactions, including status seeking [37], social network positioning [38] and managerial ability [39].

Regarding the economic games designed to elicit (pro)social preferences, the literature is inconclusive as to whether and how 2D : 4D predicts subjects' social behaviour. Some studies report negative effects [40,41], whereas others indicate positive effects [42–46] on prosocial behaviours such as generosity or cooperation. Null and nonlinear (mostly quadratic) relationships have also been frequently reported [47–54]. Other studies find 2D : 4D–context interactive effects where situational cues change the relationship between 2D : 4D and social behaviour. For example, Van den Bergh & Dewitte [44] observed that lower 2D : 4D increases or decreases rejection rates (i.e. punishment) in the ultimatum game (UG) depending on whether subjects are in a neutral or sex-related context, respectively, whereas Millet & Dewitte [47] detected a negative or positive association between 2D : 4D and generosity in dictator games (DG) depending on whether or not participants are primed with aggression cues.

In sum, the existing evidence provides no specific hypothesis regarding how prenatal sex hormone exposure (as proxied by 2D : 4D) organizes (pro)social behaviour in economic games. Note that many of these papers are based on hypothetical decisions without monetary consequences.

Three features of this study distinguish it from previous research. First, we use a large sample size consisting of 560 individuals which permits high statistical power.

Second, we elicit five dimensions of social behaviour using three economic games with real monetary stakes. Our participants decided as Dictators in a DG (see [51,55]) measuring generosity, as both Proposers and Responders in the UG (see [56]) measuring bargaining and punishment behaviour, and as both Trustors and Trustees in the trust game (TG) (see [57]) measuring trust and reciprocity (see Material and methods). Previous studies suggest there might be sex differences: women are more generous [55], males trust more, but women are more trustworthy [58]. Evidence on sex differences in bargaining and punishment is mixed and there is some indication that the counterpart's sex might play a role in UG behaviour [59,60]. Thus, sexually dimorphic (biological) traits such as prenatal hormone exposure may potentially predict behaviour in these games.

Finally, our dataset enables controlling for a number of potential confounding factors, including cognitive reflection [61,62] or risk preferences [63,64] (see electronic supplementary material).

2. Material and methods

(a) Participants and protocol

The experiment was conducted in October 2011 at the EGEO Laboratory of the University of Granada. The sample comprised 560 Caucasian subjects (330 females; age: mean ± s.d. = 17.97 ± 1.82). Participants were first asked to complete the sociodemographic and personality characteristics section, including self-reported life satisfaction, risk preferences and social capital. In addition, the survey contained a math test with four simple questions. After the survey, the subjects played the economic games in random order. Finally, they completed the cognitive reflection test [65]. These variables are used as controls in the regression analysis. Below, we briefly explain the elicitation and structure of our three main variable types. More details about the procedures are reported in the electronic supplementary material.

After completing the tasks, a research assistant scanned both hands of all the participants using a high-resolution scanner. The same researcher measured the finger lengths twice from the images using Photoshop. The two resulting 2D : 4D measurements were averaged to obtain a single 2D : 4D ratio value for each hand. As expected, the left-hand and right-hand 2D : 4Ds were positively correlated ($r = 0.67$, $p < 0.001$ for males; $r = 0.71$, $p < 0.001$ for females; Pearson correlation) and males displayed lower 2D : 4D than females (right-hand means ± s.d.: $2D:4D_M = 0.960 \pm 0.033$, $2D:4D_F = 0.972 \pm 0.033$, $p < 0.001$; left-hand means: $2D:4D_M = 0.965 \pm 0.032$, $2D:4D_F = 0.976 \pm 0.032$, $p < 0.001$; *t*-test; see electronic supplementary material).

(b) Social behaviour measurement: economic games

Our experiment consisted of three canonical two-person games: the DG, UG and TG. As is standard in economic laboratory experiments, participants made their decisions individually on their computers and never learnt the identity of the person they were (randomly) matched with.

In the DG, the Dictator had to divide €20 between herself and another anonymous participant, the Receiver, who had to accept the offer. The amount donated to the other participant (*DG offer*) was our measure of generosity.

In the UG ([56]; see electronic supplementary material, figure S1), the Proposer proposed a division of €20 between herself and another anonymous participant, the Responder, who—unlike the DG—could either accept or reject the proposal. If the Responder accepted, the proposed division was implemented; in the case of rejection, neither participant earned anything. Each subject participated in both roles. The *offer* made to the Responder was our measure of the Proposers' bargaining behaviour. For the role of Responder, we used the minimum acceptable offer (*mao*), typically interpreted as indicative of the Responder's willingness to punish (unfair) Proposers at a personal cost [1,5,22,66,67].

We employed a binary version of TG [68]. Player 1, the Trustor, had to decide whether to give the Trustee €10 or €0. If she gave €0, the Trustor earned €10 and the Trustee nothing; if she gave €10, the Trustee received 4 × €10 = €40. In this case, the Trustee had to decide whether to return €22 and keep €18 for herself (that is, be trustworthy) or keep all €40 without returning anything. The Trustor's decision thus measures trust, whereas the Trustee's decision measures reciprocity (see electronic supplementary material, figure S1).

Decisions were not hypothetical. Participants' payoffs were computed according to their decisions in the games and those of a randomly matched participant. One of every 10 participants was randomly selected for payment, and the final pay-off was determined by a randomly selected role (from the six possible roles, including as Receiver in the DG, which is passive). Previous studies have shown that this payment method yields reliable data in economic experiments (see [69,70]). The average earnings of those selected for payment, including those winning €0 (11.43%), were €10.43. Descriptive statistics and bivariate correlations of the game outcomes and variables are shown in electronic supplementary material, tables S1 and S2.

3. Results

Electronic supplementary material, tables S3–S7 report the estimates of a series of models in which we regress the behaviour in a particular role in a particular game on the combinations of 2D : 4D, 2D : 4D-squared (to analyse non-linear, quadratic relationships; [50,64]), and a gender dummy variable (including interactions). The models were conducted with and without control variables and for the left and right hands separately.

Our analyses give a clear message: 2D : 4D is not systematically related to the subjects' behaviour in any game. Independently of the outcome variable and model specification, in a total of 40 regressions, 2D : 4D did not have a single effect at the 5% significance level. The few significant effects at the 10% level disappear when including additional control variables and/or adjusting for multiple comparisons. Additionally, the gender dummy variable is never significant (*t*-tests and proportion tests comparing males and females' behaviour always yield $p > 0.16$; see electronic supplementary material, table S2).

Hence, 2D : 4D is not systematically related to behaviour in our data and the effects do not depend on gender. Since multiple comparison correction only corroborates the null findings from electronic supplementary material, tables SM3–SM7, they are not reported.

We also performed a factor analysis as a robustness check to exclude the possibility of measurement errors distorting our estimates [54,71]. As in previous studies [54,72], our analysis supports the existence of an underlying factor common to *DG offer*, *UG offer*, *TG trust* and *TG reciprocity*, but not *UG mao*. However, confirmatory latent variable analysis using structural equation modelling fails to detect any association between 2D : 4D and the latent 'prosociality' obtained in the eight model specifications estimated for each hand (results available upon request).

4. Discussion

This article contributes to the literature analysing the link between prenatal exposure to testosterone/oestrogen and prosocial behaviour in economic games. We investigate this question using three canonical two-person games—DG, UG and TG—with real monetary incentives.

Our experimental set-up comprises five different dimensions of social behaviour: generosity, bargaining, punishment, trust and reciprocity. It is worth remarking that we use a large sample of Caucasian participants ($n = 560$) with enough power to find a small effect size (specifically, $r = 0.12$) with 80% power and $\alpha = 0.05$.

For both males and females, we find no robust association between right/left-hand 2D : 4D and generosity, bargaining or trust-related behaviours in any of the 40 regressions. These results are in line with recent evidence in Candelo & Eckel [52] and Parslow *et al*. [53], who analyse DG giving in a sample of 115 African-Americans and 330 Swedish women, respectively. In a larger sample using a larger number of incentivized decisions, our results corroborate the lack of a direct relationship. We also fail to find significant sex differences in social behaviour, in contrast with previous research [55,58]. It might be that a significant 2D : 4D–prosociality relationship is observed in samples where there are sex differences, which is not our case. Future work should tackle this question.

How can we reconcile the different findings in the literature on the association between 2D : 4D and (pro)social behaviour? It has been argued that—similarly to its circulating counterpart [26,73]—prenatal testosterone can be understood as a marker for social status [74]. The evidence indeed suggests that the association between 2D : 4D and other traits is moderated by the context and its relation to status attainment. Low 2D : 4D (reflecting *high* testosterone exposure) robustly predicts aggressive or retaliation behaviour only if status is at stake or aggression is provoked [43,45], while many inconsistencies arise in neutral settings [74,75]. Furthermore, the association is more robust using real-life behaviours and outcomes than hypothetical and laboratory environments [76]. Similarly, Brañas-Garza *et al*. [64] reported a correlation between risk-taking and 2D : 4D only if the elicitation of risk attitudes is incentivized—and thus potentially relevant for status attainment—but not in a hypothetical task. Millet & Buehler [76] provided a direct test of the moderating effect of status-related framing and found strong evidence supporting this hypothesis. These examples are in line with the status- or dominance-related interpretation of the 2D : 4D-behaviour linkage [74]. According to this interpretation, fetal testosterone mainly manifests itself through enhancing the sensitivity to its circulating counterpart, supported by the observation that administered testosterone only affects low 2D : 4D individuals ([77,78]; see also [76]). The role of circulating testosterone in status-related situations is widely documented [22,23,27].

The above discussion might also explain the diverse findings on social behaviour: social behaviour might be affected by contextual variables similarly and not controlling for the context might generate omitted-variable issues [74]. In our neutral setting without priming status, dominance or competition but in which all tasks are incentivized, neither (pro)sociality nor selfishness is *ex ante* status-enhancing and we may expect—and find—no systematic relation between 2D : 4D and behaviour. This is in line with recent arguments that 2D : 4D might be a biomarker for (prenatal and adult) sex hormones solely in challenging situations [79]. The UG *mao* case is worth noting. Previous studies suggest that relative standing or status, and not fairness *per se*, is an important concern in UG rejections [80–82]. However, other studies have found evidence that both 'prosocial' and 'antisocial' punishers coexist in the UG. High *mao* might then emanate from a desire either to impose fairness or maintain one's relative standing [67], beyond other motives [83]. Thus, rejections in the UG may stem from multiple motivations. Future research should explore these possibilities.

Ethics. All participants were informed about the content of the experiment before they participated and provided written consent.

Besides, their anonymity was always preserved (in agreement with the Spanish Law 15/1999 for Personal Data Protection) by assigning them a random numerical code, which would identify them in the system. No association was ever made between their real names and the results. As is standard in socio-economic experiments, no ethic concerns are involved other than preserving the anonymity of participants. This procedure was checked and approved by the Vice Dean of Research of the School of Economics of the University of Granada, the institution hosting the experiment.

Data accessibility. Data are available from the Dryad Digital Repository at: https://doi.org/10.5061/dryad.rn288jt [84].

Authors' contributions. P.B.-G. conceived of the study, designed the experiment and drafted the paper. A.M.E. designed the experiment, conducted the laboratory sessions, analysed the data and drafted the paper. T.G.-M. coordinated the study, conducted the laboratory sessions and analysed the data and edited the paper. J.K. analysed the data and drafted the paper. All authors gave final approval for publication and agree to be held accountable for the work performed therein.

Competing interests. We declare no competing interests.

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References

1. Fehr E, Fischbacher U. 2003 The nature of human altruism. *Nature* **425**, 785–791. (doi:10.1038/nature02043)
2. Ebstein RP, Israel S, Chew SH, Zhong S, Knafo A. 2010 Genetics of human social behavior. *Neuron* **65**, 831–844. (doi:10.1016/j.neuron.2010.02.020)
3. Corgnet B, Espín AM, Hernán-González R, Kujal P, Rassenti S. 2016 To trust, or not to trust: cognitive reflection in trust games. *J. Behav. Exp. Econ.* **64**, 20–27. (doi:10.1016/j.socec.2015.09.008)
4. Espín AM, Exadaktylos F, Neyse L. 2016 Heterogeneous motives in the trust game: a tale of two roles. *Front. Psychol.* **7**, 728. (doi:10.3389/fpsyg.2016.00728)
5. Henrich J *et al.* 2005 Economic man in cross-cultural perspective: behavioral experiments in 15 small-scale societies. *J. Behav. Brain Sci.* **28**, 795–815. (doi:10.1017/S0140525X05000142)
6. Henrich J *et al.* 2010 Markets, religion, community size, and the evolution of fairness and punishment. *Science* **327**, 1480–1484. (doi:10.1126/science.1182238)
7. Herrmann B, Thöni C, Gächter S. 2008 Antisocial punishment across societies. *Science* **319**, 1362–1367. (doi:10.1126/science.1153808)
8. Wallace B, Cesarini D, Lichtenstein P, Johannesson M. 2007 Heritability of ultimatum game responder behavior. *Proc. Natl Acad. Sci. USA* **104**, 15 631–15 634. (doi:10.1073/pnas.0706642104)
9. Cesarini D, Dawes CT, Fowler JH, Johannesson M, Lichtenstein P, Wallace B. 2008 Heritability of cooperative behavior in the trust game. *Proc. Natl Acad. Sci. USA* **105**, 3721–3726. (doi:10.1073/pnas.0710069105)
10. Wingfield JC, Maney DL, Breuner CW, Jacobs JD, Lynn S, Ramenofsky M, Richardson RD. 1998 Ecological bases of hormone–behavior interactions: the 'emergency life history stage'. *Am. Zool.* **38**, 191–206. (doi:10.1093/icb/38.1.191)
11. Repetti RL, Taylor SE, Seeman TE. 2002 Risky families: family social environments and the mental and physical health of offspring. *Psychol. Bull.* **128**, 330–366. (doi:10.1037/0033-2909.128.2.330)
12. Fries ABW, Ziegler TE, Kurian JR, Jacoris S, Pollak SD. 2005 Early experience in humans is associated with changes in neuropeptides critical for regulating social behavior. *Proc. Natl Acad. Sci. USA* **102**, 17 237–17 240. (doi:10.1073/pnas.0504767102)
13. Knickmeyer R, Baron-Cohen S, Raggatt P, Taylor K. 2005 Foetal testosterone, social relationships, and restricted interests in children. *J. Child Psychol. Psychiatry* **46**, 198–210. (doi:10.1111/j.1469-7610.2004.00349.x)
14. Auyeung B, Baron-Cohen S, Ashwin E, Knickmeyer R, Taylor K, Hackett G, Hines M. 2009 Fetal testosterone predicts sexually differentiated childhood behavior in girls and in boys. *Psychol. Sci.* **20**, 144–148. (doi:10.1111/j.1467-9280.2009.02279.x)
15. Berenbaum SA, Beltz AM. 2011 Sexual differentiation of human behavior: effects of prenatal and pubertal organizational hormones. *Front. Neuroendocrinol.* **32**, 183–200. (doi:10.1016/j.yfrne.2011.03.001)
16. Baron-Cohen S, Knickmeyer RC, Belmonte MK. 2005 Sex differences in the brain: implications for explaining autism. *Science* **310**, 819–823. (doi:10.1126/science.1115455)
17. Cohen-Bendahan CC, Van de Beek C, Berenbaum SA. 2005 Prenatal sex hormone effects on child and adult sex-typed behavior: methods and findings. *Neurosci. Biobehav. Rev.* **29**, 353–384. (doi:10.1016/j.neubiorev.2004.11.004)
18. Davis EP, Sandman CA. 2010 The timing of prenatal exposure to maternal cortisol and psychosocial stress is associated with human infant cognitive development. *Child Dev.* **81**, 131–148. (doi:10.1111/j.1467-8624.2009.01385.x)
19. Lombardo MV, Ashwin E, Auyeung B, Chakrabarti B, Lai MC, Taylor K, Hackett G, Bullmore ET, Baron-Cohen S. 2012 Fetal programming effects of testosterone on the reward system and behavioral approach tendencies in humans. *Biol. Psychiatry* **72**, 839–847. (doi:10.1016/j.biopsych.2012.05.027)
20. Harris JA, Vernon PA, Boomsma DI. 1998 The heritability of testosterone: a study of Dutch adolescent twins and their parents. *Behav. Genet.* **28**, 165–171. (doi:10.1023/A:1021466929053)
21. Bartels M, Van den Berg SM, Sluyter F, Boomsma DI, de Geus EJC. 2003 Heritability of cortisol levels: review and simultaneous analysis of twin studies. *Psychoneuroendocrinology* **28**, 121–137. (doi:10.1016/S0306-4530(02)00003-3)
22. Burnham TC. 2007 High-testosterone men reject low ultimatum game offers. *Proc. R. Soc. B* **274**, 2327–2330. (doi:10.1098/rspb.2007.0546)
23. Zak PJ, Kurzban R, Ahmadi S, Swerdloff RS, Park J, Efremidze L, Redwine K, Morgan K, Matzner W. 2009 Testosterone administration decreases generosity in the ultimatum game. *PLoS ONE* **4**, e8330. (doi:10.1371/journal.pone.0008330)
24. Zethraeus N, Kocoska-Maras L, Ellingsen T, Von Schoultz BO, Hirschberg AL, Johannesson M. 2009 A randomized trial of the effect of estrogen and testosterone on economic behavior. *Proc. Natl Acad. Sci. USA* **106**, 6535–6538. (doi:10.1073/pnas.0812757106)
25. Bos PA, Terburg D, Van Honk J. 2010 Testosterone decreases trust in socially naive humans. *Proc. Natl Acad. Sci. USA* **107**, 9991–9995. (doi:10.1073/pnas.0911700107)
26. Eisenegger C, Haushofer J, Fehr E. 2011 The role of testosterone in social interaction. *Trends Cogn. Sci.* **15**, 263–271. (doi:10.1016/j.tics.2011.04.008)
27. Eisenegger C, Naef M, Snozzi R, Heinrichs M, Fehr E. 2010 Prejudice and truth about the effect of testosterone on human bargaining behaviour. *Nature* **463**, 356–359. (doi:10.1038/nature08711)
28. Van Honk J, Montoya ER, Bos PA, Van Vugt M, Terburg D. 2012 New evidence on testosterone and cooperation. *Nature* **485**, E4. (doi:10.1038/nature11136)
29. Lutchmaya S, Baron-Cohen S, Raggatt P, Knickmeyer R, Manning JT. 2004 2nd to 4th digit ratios, fetal testosterone and estradiol. *Early Hum. Dev.* **77**, 23–28. (doi:10.1016/j.earlhumdev.2003.12.002)
30. Talarovičová A, Kršková L, Blažeková J. 2009 Testosterone enhancement during pregnancy influences the 2D : 4D ratio and open field motor activity of rat siblings in adulthood. *Horm. Behav.* **55**, 235–239. (doi:10.1016/j.yhbeh.2008.10.010)
31. Auger J, Le Denmat D, Berges R, Doridot L, Salmon B, Canivenc-Lavier MC, Eustache F. 2013 Environmental levels of oestrogenic and antiandrogenic compounds feminize digit ratios in male rats and their unexposed male progeny. *Proc. R. Soc. B* **280**, 20131532. (doi:10.1098/rspb.2013.1532)
32. Romano M, Rubolini D, Martinelli R, Alquati AB, Saino N. 2005 Experimental manipulation of

yolk testosterone affects digit length ratios in the ring-necked pheasant (*Phasianus colchicus*). *Horm. Behav.* **48**, 342–346. (doi:10.1016/j.yhbeh.2005.03.007)

33. Richards G. 2017 What is the evidence for a link between digit ratio (2D : 4D) and direct measures of prenatal sex hormones? *Early Hum. Dev.* **113**, 71–72. (doi:10.1016/j.earlhumdev.2017.08.003)
34. Richards G, Gomes MC, Ventura T. 2018 Testosterone measured from amniotic fluid and maternal plasma shows no significant association with directional asymmetry in newborn digit ratio (2D : 4D). *J. Dev. Orig. Health Dis.* **10**, 362–367. (doi:10.1017/s2040174418000752)
35. Manning JT. 2002 *Digit ratio: a pointer to fertility, behavior, and health*. New Brunswick, NJ: Rutgers University Press.
36. Hönekopp J, Watson S. 2010 Meta-analysis of digit ratio 2D : 4D shows greater sex difference in the right hand. *Am. J. Hum. Biol.* **22**, 619–630. (doi:10.1002/ajhb.21054)
37. Manning JT, Fink B. 2008 Digit ratio (2D : 4D), dominance, reproductive success, asymmetry, and sociosexuality in the BBC Internet Study. *Am. J. Hum. Biol.* **20**, 451–461. (doi:10.1002/ajhb.20767)
38. Kovářík J, Brañas-Garza P, Davidson MW, Haim DA, Carcelli S, Fowler JH. 2017 Digit ratio (2D : 4D) and social integration: an effect of prenatal sex hormones. *Netw. Sci.* **5**, 476–489. (doi:10.1017/nws.2017.4)
39. Guiso L, Rustichini A. 2018 What drives women out of management? The joint role of testosterone and culture. *Eur. Econ. Rev.* **109**, 221–237. (doi:10.1016/j.euroecorev.2017.10.008)
40. Cecchi F, Duchoslav J. 2018 The effect of prenatal stress on cooperation: evidence from violent conflict in Uganda. *Eur. Econ. Rev.* **101**, 35–56. (doi:10.1016/j.euroecorev.2017.09.015)
41. De Neys W, Hopfensitz A, Bonnefon JF. 2013 Low second-to-fourth digit ratio predicts indiscriminate social suspicion, not improved trustworthiness detection. *Biol. Lett.* **9**, 20130037. (doi:10.1098/rsbl.2013.0037)
42. Millet K, Dewitte S. 2006 Second to fourth digit ratio and cooperative behavior. *Biol. Psychol.* **71**, 111–115. (doi:10.1016/j.biopsycho.2005.06.001)
43. Millet K, Dewitte S. 2007 Digit ratio (2D : 4D) moderates the impact of an aggressive music video on aggression. *Pers. Individ. Dif.* **43**, 289–294. (doi:10.1016/j.paid.2006.11.024)
44. Van den Bergh B, Dewitte S. 2006 Digit ratio (2D : 4D) moderates the impact of sexual cues on men's decisions in ultimatum games. *Proc. R. Soc. B* **273**, 2091–2095. (doi:10.1098/rspb.2006.3550)
45. Ronay R, Galinsky AD. 2011 Lextalionis: testosterone and the law of retaliation. *J. Exp. Soc. Psychol.* **47**, 702–705. (doi:10.1016/j.jesp.2010.11.009)
46. Buser T. 2012 Digit ratios, the menstrual cycle and social preferences. *Games Econ. Behav.* **76**, 457–470. (doi:10.1016/j.geb.2012.07.006)
47. Millet K, Dewitte S. 2009 The presence of aggression cues inverts the relation between digit ratio (2D : 4D) and prosocial behaviour in a dictator game. *Br. J. Psychol.* **100**, 151–162. (doi:10.1348/000712608X324359)
48. Sanchez-Pages S, Turiegano E. 2010 Testosterone, facial symmetry and cooperation in the prisoners' dilemma. *Physiol. Behav.* **99**, 355–361. (doi:10.1016/j.physbeh.2009.11.013)
49. Sanchez-Pages S, Turiegano E. 2013 Two studies on the interplay between social preferences and individual biological features. *Behaviour* **150**, 713–735. (doi:10.1163/1568539X-00003077)
50. Brañas-Garza P, Kovářík J, Neyse L. 2013 Second-to-fourth digit ratio has a non-monotonic impact on altruism. *PLoS ONE* **8**, e60419. (doi:10.1371/journal.pone.0060419)
51. Galizzi MM, Nieboer J. 2015 Digit ratio (2D : 4D) and altruism: evidence from a large, multi-ethnic sample. *Front. Behav. Neurosci.* **9**, 41. (doi:10.3389/fnbeh.2015.00041)
52. Candelo N, Eckel C. 2018 The 2D : 4D ratio does not always correlate with economic behavior: a field experiment with African-Americans. *Econ. Hum. Biol.* **30**, 172–181. (doi:10.1016/j.ehb.2018.07.002)
53. Parslow E, Ranehill E, Zethraeus N, Blomberg L, von Schoultz B, Lind A, Johannesson M, Dreber A. 2018 The digit ratio (2D : 4D) and economic preferences: no robust associations in a sample of 330 women. *mimeo*.
54. Kaltwasser L, Mikac U, Buško V, Hildebrandt A. 2017 No robust association between static markers of testosterone and facets of socio-economic decision making. *Front. Behav. Neurosci.* **11**, 250. (doi:10.3389/fnbeh.2017.00250)
55. Brañas-Garza P, Capraro V, Rascon-Ramirez E. 2018 Gender differences in altruism on Mechanical Turk: expectations and actual behaviour. *Econ. Lett.* **170**, 19–23. (doi:10.1016/j.econlet.2018.05.022)
56. Güth W, Schmittberger R, Schwarze B. 1982 An experimental analysis of ultimatum bargaining. *J. Econ. Behav. Organ.* **3**, 367–388. (doi:10.1016/0167-2681(82)90011-7)
57. Bohnet I, Zeckhauser R. 2004 Trust, risk and betrayal. *J. Econ. Behav. Organ.* **55**, 467–484. (doi:10.1016/j.jebo.2003.11.004)
58. Buchan NR, Croson RT, Solnick S. 2008 Trust and gender: an examination of behavior and beliefs in the investment game. *J. Econ. Behav. Organ.* **68**, 466–476. (doi:10.1016/j.jebo.2007.10.006)
59. Li S, Qin X, Houser D. 2018 Revisiting gender differences in ultimatum bargaining: experimental evidence from the US and China. *J. Econ. Sci. Assoc.* **4**, 180–190. (doi:10.1007/s40881-018-0054-5)
60. Solnick SJ. 2001 Gender differences in the ultimatum game. *Econ. Inquiry* **39**, 189–200. (doi:10.1111/j.1465-7295.2001.tb00060.x)
61. Bosch-Domènech A, Brañas-Garza P, Espín AM. 2014 Can exposure to prenatal sex hormones (2D : 4D) predict cognitive reflection? *Psychoneuroendocrinology* **43**, 1–10. (doi:10.1016/j.psyneuen.2014.01.023)
62. Cueva C, Iturbe-Ormaetxe I, Mata-Pérez E, Ponti G, Sartarelli M, Yu H, Zhukova V. 2016 Cognitive (ir)reflection: new experimental evidence. *J. Behav. Exp. Econ.* **64**, 81–93. (doi:10.1016/j.socec.2015.09.002)
63. Brañas-Garza P, Rustichini A. 2011 Organizing effects of testosterone and economic behavior: not just risk taking. *PLoS ONE* **6**, e29842. (doi:10.1371/journal.pone.0029842)
64. Brañas-Garza P, Galizzi M, Nieboer J. 2018 Experimental and self-reported measures of risk taking and digit ratio (2D : 4D): evidence from a large, systematic study. *Int. Econ. Rev.* **59**, 1131–1157. (doi:10.1111/iere.12299)
65. Frederick S. 2005 Cognitive reflection and decision making. *J. Econ. Perspect.* **19**, 25–42. (doi:10.1257/089533005775196732)
66. Brañas-Garza P, Cobo-Reyes R, Domínguez A. 2006 Si él lo necesita: gypsy fairness in Vallecas. *Exp. Econ.* **9**, 253–264. (doi:10.1007/s10683-006-9126-0)
67. Brañas-Garza P, Espín AM, Exadaktylos F, Herrmann B. 2014 Fair and unfair punishers coexist in the Ultimatum Game. *Sci. Rep.* **4**, 6025. (doi:10.1038/srep06025)
68. Ermisch J, Gambetta D, Laurie H, Siedler T, Noah Uhrig SC. 2009 Measuring people's trust. *J. R. Stat. Soc. Ser. A* **172**, 749–769. (doi:10.1111/j.1467-985X.2009.00591.x)
69. Charness G, Gneezy U, Halladay B. 2016 Experimental methods: pay one or pay all. *J. Econ. Behav. Organ.* **131**, 141–150. (doi:10.1016/j.jebo.2016.08.010)
70. Brañas-Garza P, Jorrat D, Espín AM, Sanchez A. 2019 Paid and hypothetical time preferences are the same: lab, field and online evidence. *mimeo.*
71. Kaltwasser L, Hildebrand A, Wilhel O, Sommerab W. 2017 On the relationship of emotional abilities and prosocial behavior. *Evol. Hum. Behav.* **38**, 298–308. (doi:10.1016/j.evolhumbehav.2016.10.011)
72. Peysakhovich A, Nowak MA, Rand DG. 2014 Humans display a 'cooperative phenotype' that is domain general and temporally stable. *Nat. Commun.* **5**, 4939. (doi:10.1038/ncomms5939)
73. Mazur A, Booth A. 1998 Testosterone and dominance in men. *J. Behav. Brain Sci.* **21**, 353–363. (doi:10.1017/S0140525X98001228)
74. Millet K. 2011 An interactionist perspective on the relation between 2D : 4D and behavior: an overview of (moderated) relationships between 2D : 4D and economic decision making. *Pers. Individ. Dif.* **51**, 397–401. (doi:10.1016/j.paid.2010.04.005)
75. Ryckmans J, Millet K, Warlop L. 2015 The influence of facial characteristics on the relation between male 2D : 4D and dominance. *PLoS ONE* **10**, e0143307. (doi:10.1371/journal.pone.0143307)
76. Millet K, Buehler F. 2018 A context dependent interpretation of inconsistencies in 2D : 4D findings: the moderating role of status relevance. *Front. Behav. Neurosci.* **11**, 254. (doi:10.3389/fnbeh.2017.00254)
77. Buskens V, Raub W, Van Miltenburg N, Montoya ER, Van Honk J. 2016 Testosterone administration moderates effect of social environment on trust in women depending on second-to-fourth digit ratio. *Sci. Rep.* **6**, 27655. (doi:10.1038/srep27655)
78. Chen C, Decety J, Huang PC, Chen CY, Cheng Y. 2016 Testosterone administration in females modulates moral judgment and patterns of brain activation and functional connectivity. *Hum. Brain Mapp.* **37**, 3417–3430. (doi:10.1002/hbm.23249)

79. Manning J, Kilduff L, Cook C, Crewther B, Fink B. 2014 Digit ratio (2D : 4D): a biomarker for prenatal sex steroids and adult sex steroids in challenge situations. *Front. Endocrinol.* **5**, 9. (doi:10.3389/fendo.2014.00009)
80. Yamagishi T *et al.* 2012 Rejection of unfair offers in the ultimatum game is no evidence of strong reciprocity. *Proc. Natl Acad. Sci. USA* **109**, 20 364–20 368. (doi:10.1073/pnas.1212126109)
81. Yamagishi T, Horita Y, Takagishi H, Shinada M, Tanida S, Cook KS. 2009 The private rejection of unfair offers and emotional commitment. *Proc. Natl Acad. Sci. USA* **106**, 11 520–11 523. (doi:10.1073/pnas.0900636106)
82. Espín AM, Exadaktylos F, Herrmann B, Brañas-Garza P. 2015 Short-and long-run goals in ultimatum bargaining: impatience predicts spite-based behavior. *Front. Behav. Neurosci.* **9**, 214. (doi:10.3389/fnbeh.2015.00214)
83. Staffiero G, Exadaktylos F, Espín AM. 2013 Accepting zero in the ultimatum game does not reflect selfish preferences. *Econ. Lett.* **121**, 236–238. (https://doi.org/10.5061/dryad.rn288jt)
84. Brañas-Garza P, Espín AM, García-Muñoz T, Kovářík J. 2019 Data from: Digit ratio (2D : 4D) and prosocial behaviour in economic games: no direct correlation with generosity, bargaining or trust-related behaviours. Dryad Digital Repository. (https://doi.org/10.5061/dryad.rn288jt)