Network Science
Forthcoming

Digit ratio (2D:4D) and social integration: an effect of prenatal sex hormones

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July 9, 2016

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Abstract

The position people occupy in their social and professional networks is related to their social status and has strong effects on their access to social resources. While attainment of particular positions is driven by behavioral traits, many biological factors predispose individuals to certain behaviors and motivations. Prior work on exposure to fetal androgens (measured by second-to-fourth digit ratio, 2D:4D) shows that it correlates with behaviors and traits related to social status, which might make people more socially integrated. However, it also predicts certain anti-social behaviors and disorders associated with lower socialization. We explore whether 2D:4D correlates with network position later in life and find that individuals with low 2D:4D become more central in their social environment. Interestingly, low 2D:4D males are more likely to exhibit high betweenness centrality (they connect separated parts of the social structure) while low 2D:4D females are more likely to exhibit high in-degree centrality (more people name them as friends). These gender-specific differences are reinforced by transitivity (the likelihood that one's friends are also friends with one another): neighbors of low 2D:4D men tend not to know each other; the contrary is observed for low 2D:4D women. Our results suggest that biological predispositions influence the organization of human societies and that exposure to prenatal androgens influences different status seeking behaviors in men and women.

Introduction

Social and professional network structures play an important role in the development of social status and the attainment of many individual socio-economic outcomes [1–8]. While socially developed personality traits and behaviors influence one's position in social structures [9–13], many of these traits are shaped by one's biology. Specifically, a large literature connects exposure to prenatal androgens to a wide variety of behavioral traits and motivations that may have strong effects on social relationships [14–23]. But, to date, none of this research has addressed an important question: does exposure to prenatal androgen influence one's position in social networks?

The theoretical network formation literature mostly assumes that people are homogeneous and all differences in structural position arise due to linking dynamics [24–26]. However, empirical work shows that the positions people occupy in social structures correlate with individual traits and behaviors [9–13,27]. Even though this suggests that individual heterogeneity influences network formation, causality is hard to establish due to the coevolution of many individual characteristics and social relationships.

An important step towards causal identification in network formation is the use of genetic factors underlying traits that shape social structure [28,29]. Since genotypes are mostly stable over the life course, an association between genes and networks suggests that biology influences social networks rather than the other way around. Studies that compare monozygotic ("identical") and dizygotic ("fraternal") twins suggest that in-degree, betweenness centrality, and transitivity have a genetic basis, but out-degree does not [28]. However, these studies cannot assess *which* biological traits influence network formation and whether the same traits may influence males and females differently. This question is crucial for further understanding of the biological basis of network formation and individual variation in positions, as well as for the interpretation of the findings from twin studies.

Several traits that shape social relationships and larger structural positions are shaped by exposure to prenatal androgens. Exposure to these hormones in the womb affects the development of the brain and the way these circulating hormones influence behavior later in life [30–32]. A commonly used biomarker for exposure to prenatal sex hormones is the ratio between the lengths of the index and ring fingers from the metacarpophalangeal crease to the finger tip (Figure 1). This second-to-fourth digit ratio (2D:4D) is negatively associated with exposure to testosterone and positively associated with exposure to oestrogen while in uterus. The ratio is also sexually dimorphic (men have lower values than women, see Figure 2) and it remains unchanged after early childhood [33–35].

Previous studies find that exposure to these hormones is associated with social status seeking [14], risk preference [15], cooperativeness [17], and a wide variety of other behavioral characteristics [18–20]. All of these traits plausibly influence social relationships and might thus affect structural positions in social networks. In addition, lower 2D:4D is predictive of attractiveness [36], and success in sports [37,38], finance [39], education [40], and the arts [41], all of which may in turn lead to high social status. Because status is naturally connected with network positions [44], we hypothesize that low 2D:4D individuals will tend to occupy important locations in social structures.

However, low 2D:4D individuals are also more likely to exhibit certain behaviors that are not conducive to building social relationships. For example, low 2D:4D is associated with less eye contact in children [45], anti-social aggression [46], the inhibition of cognitive empathy [16], and a variety of social disorders such as autism [21–23]. These factors might mitigate or overpower the effects of the pro-social behavioral traits associated with higher prenatal androgen exposure.

Here, we combine data on 2D:4D and a sociocentric analysis of a large group of young adults. Our subjects are 247 first-year University students surveyed once at the beginning of the school year (T1) in order to control for preexisting relationships, and a second time at the end of the school year (T2). For the analysis, we elicited social ties and mapped them in a directed network in which a link between two individuals exists if one of the individuals names the other one as a friend. See *Methods* and *Supplementary Information* (SI, hereafter) for details.

Following [28], we focus on four primary network measures (Table 1). The first, in-degree centrality, is the number of times a person is named as a friend by others. Individuals with higher in-degree centrality are popular and can be said to have higher connectivity and visibility. The second measure, out-degree centrality, is the number of friends a subject names and reflects how popular people view themselves. Third, transitivity measures the fraction of friends of a node that are also mutual friends. Hence, transitivity is a measure of local network density and reflects how relevant one is for maintaining connectivity within her network neighborhood. Nodes with high transitivity are embedded in dense neighborhoods and their removal does not greatly affect the connectivity among their neighbors. Last, betweenness is a global measure of centrality defined as the number of shortest paths between people in a network that pass through an individual [47]. Individuals with high betweenness centrality bridge the gap between different sections of the overall network and are likely to act as brokers between groups.

Observe that in-degree, out-degree, and transitivity characterize subjects' *local* positioning in the network as they are computed on the basis of their and their neighbors' links. In contrast, betweenness centrality is a *global* measure because it is affected by the ties of people to whom an individual is not directly connected. Both in-degree and betweenness depend largely on the perception of others and reflect the status one holds in the group. Meanwhile, out-degree is highly subjective and does not need to mirror how others view the individual. Consequently, it does not necessarily translate into higher status.

We match these network variables with the right-hand 2D:4D ratio of each individual in the study (see Figure 2 and *Methods*). Working with a biomarker of prenatal rather than circulating hormones and controlling for initial network formation are important elements in establishing causality. Since digit ratios remain unchanged from early childhood and do not vary across measurement periods, we can rule out the possibility of reverse causality that exists in other studies of behavioral traits and network formation. Observing the initial network allows us to account for any social ties that students may have had prior to the first measurement period and to focus on the dynamics in the new social environment.

Results

The network at T1 was sparsely connected, suggesting that students had very few ties with their peers at the beginning of the school year. At the end of the year (T2), however, the network resembles other socially generated networks in many respects (the degree distribution is skewed, there is high reciprocity and transitivity, and high-degree individuals tend to be connected to other high-degree individuals [1–3]; see Figure 3).

During the first measurement period (T1) when few students knew one another, none of the network variables is significantly associated with male or female students' 2D:4D's (see SI). During the second measurement period (T2), however, Table 2 and Figure 4 show that individuals with lower 2D:4D are more central in ways that depend on gender. Low 2D:4D females exhibit higher *local* centrality measured by in-degree ($p = 0.01$), but males do not ($p = 0.72$). In contrast, males exhibit higher *global* centrality measured by betweenness ($p = 0.04$), but females do not ($p = 0.89$). We observe that only a small part of the association between betweenness and 2D:4D in men is mediated by local degree centrality. If we control for degree at T2 in a regression analogous to (7) in Table 2, the estimated relationship decreases by 26.5% but remains significant ($p = 0.03$; see SI). The association between 2D:4D and in-degree is significantly different across genders (two-tailed test, $p = 0.04$), while it is not in case of betweenness ($p = 0.13$; see SI). Consistent with [28] who find no genetic influence on out-degree, we observe that 2D:4D is not predictive of the number of people a person names as a friend (in contrast to the number of times they are named as a friend).

The magnitudes of the relationships between 2D:4D and centrality are quite large. Holding all else equal, a female in the 10th percentile for digit ratio is 23% more likely than a woman in the 90th percentile to be named as a friend by 6 or more people (the average female in the sample was named 4.8 times in T2). Similarly, men in the 10th percentile have one-half standard deviation greater betweenness centrality than males in the 90th percentile.

A deeper analysis of gender differences shows they are reinforced by an additional association between 2D:4D and transitivity. The friends of low 2D:4D men are significantly less likely to be connected to one another ($p = 0.01$), which helps to explain why they are more globally central but not more locally central. In contrast, low 2D:4D women are significantly more likely to be embedded in transitive, densely connected neighborhoods ($p = 0.03$). As a result, the friends of women with higher exposure to prenatal testosterone (low 2D:4D) are more likely to be friends with one another, compared to high 2D:4D females. This gender difference in the association is highly significant ($p < 0.0001$). Since transitivity is typically negatively associated with connectivity [1, 2], and we observe this association in the T2 network, we again control for whether degree centrality (T2) is a mediator of the association between transitivity and 2D:4D (SI). The association among men is largely unaffected by controlling for centrality. However, for women, the estimated correlation decreases by 21.3% and remains only marginally significant ($p = 0.06$), suggesting that direct connectivity may explain some of the association between 2D:4D and transitivity in women.

To check for robustness of the results, we estimate some alternative models. First, the results generally hold if we do not control for the same network measure at the initial measurement phase T1. Second, the results are robust to pooling both genders and regressing the corresponding network measure in T2 on 2D:4D, an indicator variable for female, their interaction, and the same network measures in T1. Last, we set transitivity to zero for individuals with less than two links in Table 1, so we estimate models (5-6) removing people with no or one connection. The association is robust to this removal for men ($p = 0.05$) but weakens for women ($p = 0.33$); however, the gender difference remains strongly significant (p ¡0.0001), suggesting there is a gender difference in the relationship between 2D:4D and transitivity regardless of how it is measured. See SI Appendix for details of the robustness checks as well as information on subjects, how they were sampled, network elicitation, and the 2D:4D measurement.

Discussion

We report an association between the exposure to fetal sex hormones and social integration. Nevertheless, the association differs radically across genders. More exposure translates into more embeddedness in local circles in women (reflected in higher popularity and denser neighborhoods), a feature typically associated with high trust and cooperative environments [42, 43]. In men, high exposure leads to larger brokerage power and access to information and social resources [9, 44], manifested by bridging the gap between disconnected parts of the network. This provides direct evidence that biological characteristics shape social relationships and social network structure. Building on previous studies that established links between genetic characteristics and individual network position, we detect that prenatal hormone exposure is significantly associated with the roles that individuals play in their social environment.

An important implication of this study is that the variables observed to be associated with 2D:4D in other studies might be mediated by the effect of prenatal androgen on social network characteristics. Because no other studies in the 2D:4D literature account for social network variables, they may suffer from significant omitted variable bias. Behavioral characteristics affect social structure, but social structure also has an effect on these same behavioral characteristics. For instance, part of the reason low 2D:4D individuals might be more confident is because they occupy central positions in their social environment.

We do not have enough information to decipher *why* males and females with low digit ratios gravitate towards certain types of positions in their social environment. There are at least two mechanisms that might explain our findings. One explanation is that lower 2D:4D individuals are more *motivated* to reach advantageous positions in the social environment [53, 54]. If males and females view social 'success' differently or gain different benefits from local versus global centrality, this might explain why we observe low 2D:4D males and females systematically achieving different positions. If so, it might be a good example of an interaction effect between biology, which affects the desire to be central, and the social environment, which affects the context that is relevant for men vs. women. Perhaps these differences may be attributed to differing social roles of males and females in human societies [55].

Another possibility is that the observed correlations are due to behavioral traits that are not specifically associated with status-seeking behavior. Low 2D:4D individuals tend to be more confident, physically attractive, and have more athletic ability. Perhaps these characteristics lead individuals to *gravitate* towards the center of social networks rather than being motivated to reach these positions. Moreover, a great number of characteristics correlate with 2D:4D of men but not women and vice versa. The differences in types of centrality associated with 2D:4D in men and women might be driven by the different types of mediating characteristics that manifest in low 2D:4D men and women. For instance, studies show that 2D:4D is associated with physical aggression [48], increased eye contact [45], altruism [49], depression [50], and risk taking in health behavior [51] in men, but not necessarily in women. At the same time, 2D:4D is associated with heightened cognitive empathy [16], cooperativeness [17], and waist-to-chest ratio in women [52], but not necessarily in men. Perhaps the different ways that prenatal testosterone and oestrogen exposure manifest in the behavioral characteristics of males and females explains the different types of central positions men and women gravitate towards.

Future research should particularly target two issues. First, it is important to disentangle the above motivational, strategic explanations from those more mechanical ones. Using the data at our disposal, we cannot perform such an exercise. Second, it is important to understand which behavioral and personality traits mediate the relationship between genetic factors and social integration, and which behavioral characteristics previously found to be associated with 2D:4D are mediated by individuals' social landscape. One hypothesis is that the impact of 2D:4D on social integration may be mediated by differences between males and females in their testosterone responses to social "challenges." The link between 2D:4D and aggression in men has previously been attributed to challenge situations, or situations in which individuals face a potential aggressor. When men are faced with such an aggressor, they tend to respond with a spike in testosterone. This response and its behavioral effects are more pronounced the lower the man's 2D:4D [56]. Women, on the other hand, do not necessarily show the same responses to aggressive challenges. A recent informal meta-analysis indicated that, while men react to "winning" with a testosterone spike (possibly in preparation for the next social challenge), women may exhibit an entirely opposite response [57]. Low 2D:4D women, therefore, may respond to social challenges differently from low 2D:4D men. This differential affect of 2D:4D-related testosterone spikes on social challenges could explain the different outcomes in network positions for low 2D:4D men and women.

Our past research suggests other mediating factors. We have previously detected an association between 2D:4D and altruism [49] and altruism and network centrality [11,12]. In a different line, we correlate 2D:4D with risk attitudes [15] and risk attitudes with transitivity in [13]. Moreover, systematic gender differences in both altruism and risk aversion have been reported [58–60]. Does altruism mediate the relationship between 2D:4D and network centrality, and risk aversion between 2D:4D and transitivity? These are two interesting hypotheses for future research.

While we are able to establish neither the exact mechanisms at play nor detect the mediating factors, this study takes a step forward in establishing the specific traits that shape our social relationships and how these may operate differently for men and women.

Materials and Methods

Ethics Statement. The study was approved by the Ethical Committee of the Universidad de Granada and all subjects provided informed written consent (IC). The IC explains the content of the experiment they will perform and the payoffs attached to their performance. Anonymity was also assured and the Spanish law regarding data protection briefly explained.

Subjects. The participants were first-year undergraduate students in Economics (freshmen) at the University of Granada. In total, 247 subjects participated in at least one of the sessions; 178 subjects participated in all three measurements. 2 non-Caucasian subjects were excluded from these 178 to ensure ethnic homogeneity, resulting in sample of 176 individuals (79 females).

2D:4D measurement. Subjects were invited one by one to an office for the scanning of their both hands. Both hands were scanned with a high-resolution scanner (Canon Slide 90). We measured the lengths of the index and ring digits on both hands from basal crease to the finger tip using Adobe Professional (see [61] for more details concerning the measurement). As opposed to the network elicitation, we only scanned the hands once. However, to ensure the most accurate measurement, we measured the ratio from the scanned hands twice. The first measurement was made right after the scanning, while the second was performed 14 months later, in January 2012. In our analysis, we use the average of the first and second measurements on the right hands. The linear correlation between the first (second) measurement and the average applied in this study is 0.969 (0.968); the correlation between the two independent measurements is 0.876. The corresponding figures are 0.958, 0.957, and 0.834 for males and

0.979, 0.977, and 0.912 for females. The resulting average 2D:4D is 0.951 (SD: 0.032) for men and 0.967 (SD: 0.033) for women. Males have smaller 2D:4D's on average than females ($p < 0.001$), but the magnitude of the variation within gender is almost identical (see Figure 2). In the regression analysis, the individual 2D:4D's are thus normalized for men and women separately. Since 2D:4D is a central variable of our analysis, SI provides additional details concerning the ratio on both hands and the relationship between the left- and right-hand 2D:4D in our sample.

Social Network Elicitation. Social ties were elicited twice with the same group of undergraduate students: (T1) in the first week of their first academic year in October 2010 and (T2) at the end of the academic year in May 2011. In both 2010 and 2011, all four sections of first year students were visited and students were invited to participate in an economic experiment involving money. The participation was voluntary. Any individual who did not want to participate was allowed to leave the class before each session. Those willing to participate were seated separately, each with enough space to preserve anonymity, and they were provided with written instructions. In particular, we elicited their within-class social ties (without providing any incentives). Each participant was invited to name his friends in the whole first year, but people were instructed to name individuals for whom they knew both surnames (see [49] for more details concerning these sessions).

Data availability. All the data are available upon request from the corresponding author.

Acknowledgements

JK acknowledges financial support from Basque Government (IT-783-13), the Spanish Government (ECO2015-64467-R, ECO2015-66027-P) and the Grant Agency of the Czech Republic (14-22044S), and PBG from the Spanish Ministry of Science and Innovation (ECO2013-44879-R).

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Figure 1: An illustration of the measurement of the index (right) and ring (left) finger lengths on the right hand.

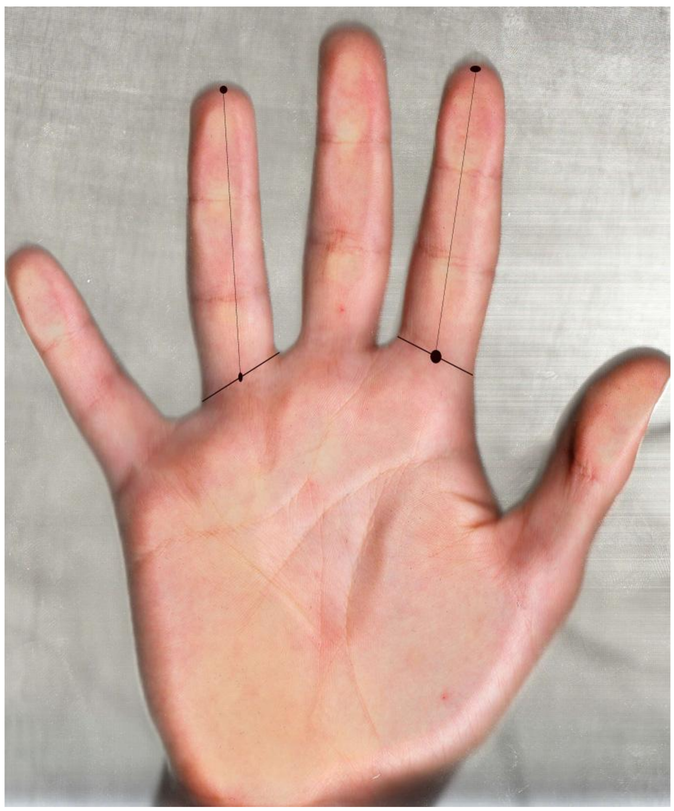
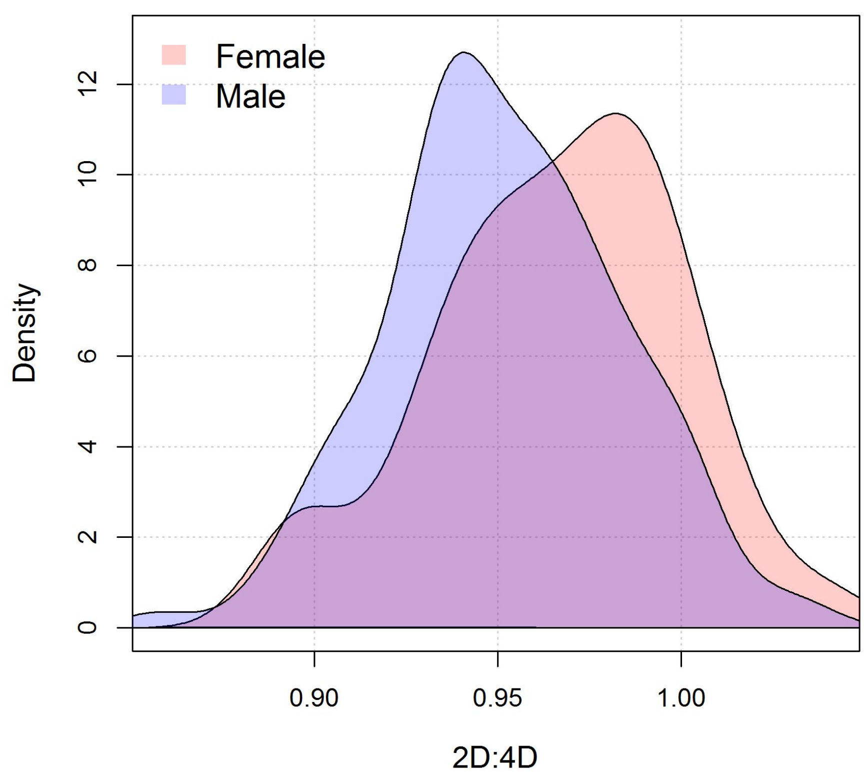


Figure 2: The distribution of the right-hand 2D:4D in our subject pool was consistent with previous studies: the trait is sexually dimorphic, with males having lower digit ratios than females on average (0.951 vs. 0.967, $p < 0.0001$). Therefore, we normalize the 2D:4D for each gender separately in the regression analysis.



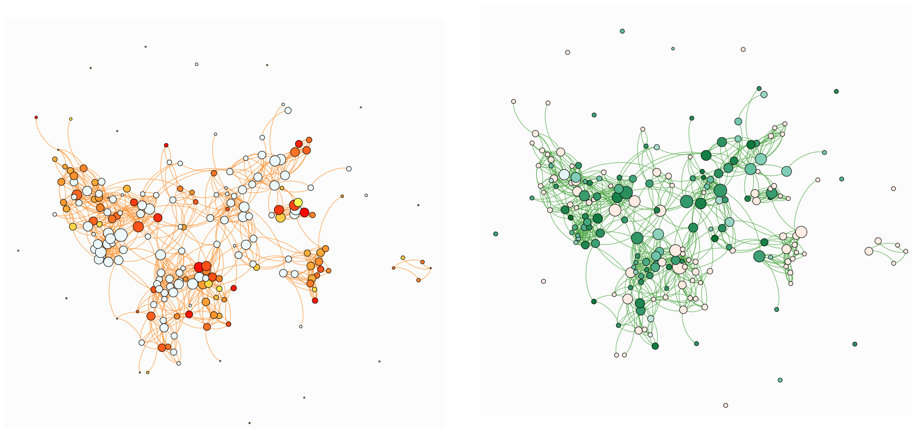


Figure 3: Elicited social network. Left: The friend network of females (colored) and males (grayed out). Vertices are sized by in-degree centrality and colored according to 2D:4D ratio (redder nodes represent smaller digit ratios). Right: The friend network of males (colored) and females (grayed out). Vertices are sized by betweenness centrality and colored according to 2D:4D ratio (greener nodes represent smaller digit ratios).

Table 1: Summary statistics of the total sample.

Variable	Mean	Std. Dev.	**N***
Female			107
Male			134
2D:4D Fem.	0.967	0.033	92
2D:4D Male	0.951	0.032	110
In-degree, T1	1.921	1.637	202
In-degree, T2	5.066	3.424	243
Out-degree, T1	1.921	1.652	202
Out-degree, T2	5.082	3.682	243
Transitivity, T1	0.306	0.379	202
Transitivity, T2	0.418	0.273	243
Betweenness (ln), T1	2.600	2.952	202
Betweenness (ln), T2	3.976	2.451	243

***N** for each variable depends on the participation.

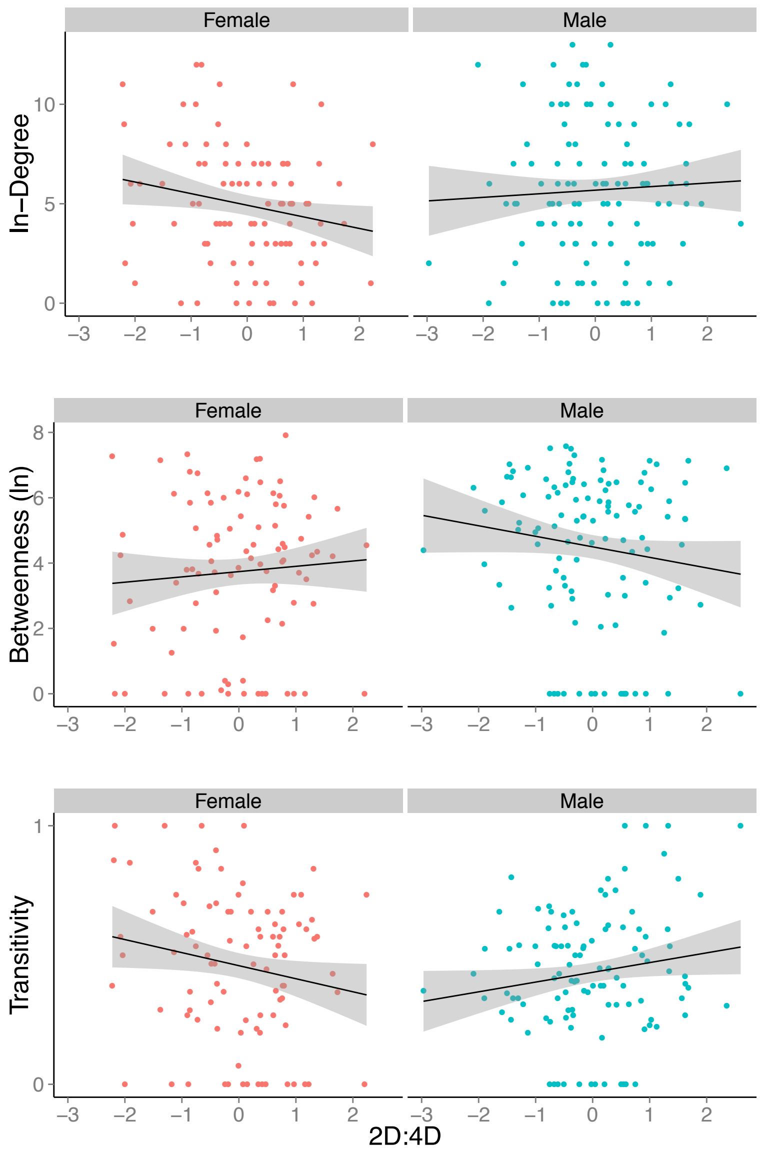


Figure 4: Raw data relationships between 2D:4D and network variables. The top row shows that low 2D:4D females exhibit higher in-degree but males do not. In contrast, the middle row shows that low 2D:4D males exhibit higher betweenness but females do not. These results are consistent with results for transitivity shown in the bottom row, which indicate that low 2D:4D females are in denser local networks while low 2D:4D males are in sparser local networks. Black lines indicate bivariate regression fit and gray regions indicate 95% confidence intervals. All results are validated by multivariate regression analyses, as shown in Table 2.

Table 2: Association of 2D:4D with in-degree, out-degree, transitivity, and betweenness centrality in the second period T2. Since in-degree and out-degree are count variables, transitivity is censored from below by 0 and from above by 1, and betweenness from below by 0 (see *SI*), we estimated ordered logit models in (1-4) and censored regresions in (5-8)

	In-degree		Out-degree		Transitivity		Betweenness (ln)	
	Male	Female	Male	Female	Male	Female	Male	Female
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
2D:4D	-.045	-.440**	-.141	.033	.065**	-.047**	-.539**	.052
	(.123)	(.178)	(.096)	(.285)	(.023)	(..021)	(.259)	(.361)
Network, T1	.201*	.140	.068	.238	.117*	.034	.170*	.119
	(.116)	(.173)	(.159)	(.206)	(.072)	(.060)	(.096)	(.098)
Constant					.432**	.430**	4.189**	3.392**
					(.051)	(.035)	(.314)	(.687)
Obs.	97	79	97	79	97	79	97	79
Pseduo R^2	.007	.018	.002	.010	.436	.023	.024	.005

St. errors robust to heteroscedasticity and clustered at section level. * p <.1, ** p <.05.

2D:4D normalized separately for men and women.

Network, T1 is the corresponding column variable at T1.

Supplementary Information Appendix for:

Prenatal Sex Hormones (2D:4D Digit Ratio) and Social Integration

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Contents

1 Appendix Introduction

This document provides additional supporting evidence for the methods and results in the main text. It contains eight supplementary tables and four supplementary figures.

2 Ethics Statement

The study was approved by the Ethical Committee of the Universidad de Granada and all subjects provided informed written consent (IC). The IC explains the content of the experiment they will perform and the payoffs attached to their performance. Anonymity was also assured and the Spanish law regarding data protection briefly explained.

3 Subjects

Participants were first-year undergraduate students in economics at the University of Granada. In total, 247 subjects participated in at least one of the sessions but 3 did not report their gender; 178 subjects participated in all measurements. 2 non-Caucasian subjects were excluded to ensure ethnic homogeneity, resulting in a sample of 176 individuals (79 females).

4 Sampling Methods

An undergraduate microeconomics course in academic year 2010-2011 was separated randomly into four groups, outlined in Table 1. To assign students to groups, a computer program was used to randomly select one surname and assign that student and the next few, in ascending or descending order, to a group until that group was filled. The next students were then assigned to the next group until it was filled, and so on. Groups A and B typically studied in adjacent rooms. Students are allowed to sit in on a different session if they so chose. Groups C and D were in the very same rooms. C and D started their classes when A and B ended. Students interacted with each other a lot and took courses in both morning and evening sessions. Those who attrited were not evaluated at the end of the year (June 2011).

5 Social Network Elicitation

Social ties were elicited twice with the same group of undergraduate students: (T1) in the first week of their first academic year in October 2010 and (T2) at the end of the academic year in May 2011. In both 2010 and 2011, all four sections of first year students were visited and students were invited to participate in an economic experiment involving money. The participation was voluntary.

Table 3:

Group	Males	Females	Attrition
A	44	27	16.9 %
B	38	33	9.8%
C	37	22	18.6%
D	63	26	33.3%

Any individual who did not want to participate was allowed to leave the class before each session. Those willing to participate were seated separately, each with enough space to preserve anonymity, and they were provided with written instructions. In particular, we elicited their within-class social ties (without providing any incentives). Each participant was invited to name his friends in the whole first year, but people were instructed to name individuals for whom they knew both surnames. Reference [1] provides further details concerning these sessions.

We did not inform students or professors before-hand that we were going to run an experiment at that day. We came to the class and we asked them to participate in the same room they were in. This negated the possibility that students who did not want to participate in the study would not show up on the day that we took measurements. We offered monetary payments for those who completed the experiments, which involved dictator games, lotteries, etc. Almost all students decided to participate before knowing that we were going to elicit networks.

6 2D:4D measurement

Subjects were invited one by one to an office for the scanning of their both hands. Both hands were scanned with a high-resolution scanner (Canon Slide 90). We measured the lengths of the index and ring digits on both hands from basal crease to the finger tip using Adobe Professional. As opposed to the network elicitation, we only scanned the hands once. However, to ensure the most accurate measurement, a research assistant with no relation to this study measured the ratio from the scanned hands twice. The first measurement was made right after the scanning, while the second was performed 14 months later, in January 2012. For each individual observation in all statistical tests in this study, we use the mean of these two measurements from the right hand. In line with the literature, we eliminated 3 non-Caucasian subjects (only 2 of them participated in the network elicitation though). This leaves us with a total of 202 observations (92 females), from which some did not participated in the network elicitation (see Table 1 in the main text). For left hands, we only have 201 2D:4D's, because one male subject had his left-hand index finger broken in the past.

In the following, we provide some statistics concerning the 2D:4D in our sample. First, regarding the right hands the linear correlation between the first (second) measurement and the average applied in this study is 0.969 (0.968) and the correlation between the two independent measurements is 0.876. The corresponding figures are 0.958, 0.957, and 0.834 for males and 0.979, 0.977, and 0.912 for females. Testing the equality of any pair of all these measurements either at the sample level or separately for men or women and either using a simple t-test or a non-parametric Wilcoxon rank-sum test always yields an extremely low p-values ($p < 2.2e^{-16}$). The resulting average 2D:4D is 0.951 (SD: 0.032) for men and 0.967 (SD: 0.033) for women. Thus, males have smaller 2D:4D's on average than females ($p < 0.001$ using simple both a two-tailed t-test or a non-parametric Wilcoxon rank-sum test), but the magnitude of the variation within gender is almost identical. In the regression analysis, we thus normalize the variable 2D:4D for men and women separately.

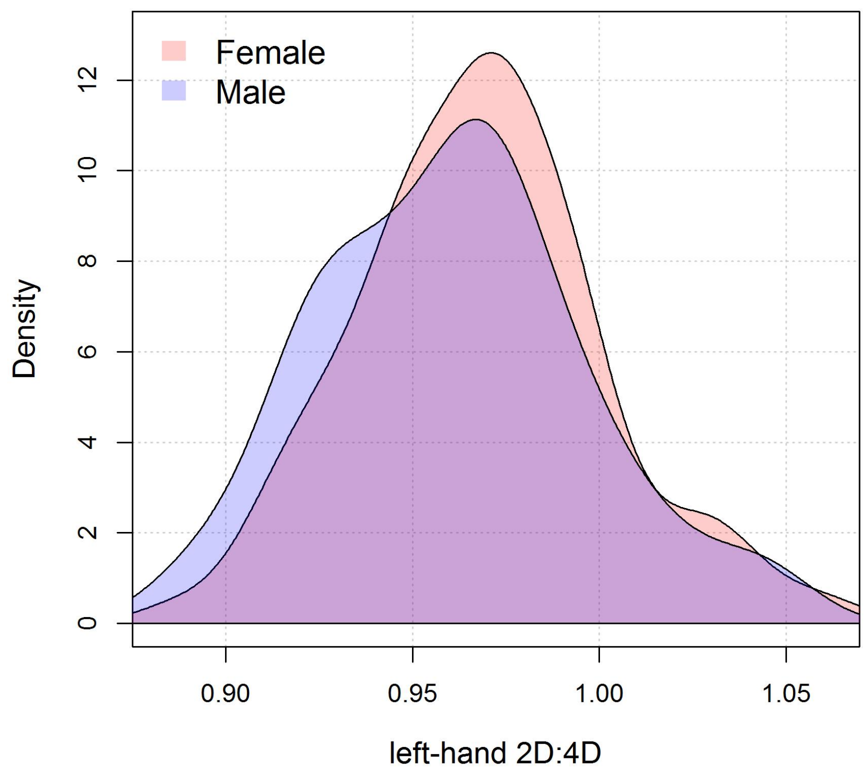
Even though we do not use the left-hand 2D:4D in this study, we summarize it here and relate to the right-hand ratios. For the sake of comparability, we have measured the left-hand 2D:4D from the scanned pictures twice and report the average. The resulting mean left-hand 2D:4D is 0.961 (SD: 0.036) for men and 0.969 (SD: 0.032) for women. The ratio is again higher for women on average, but this time the difference is not statistically significant at conventional 5% ($p = 0.196$ and 0.097 for the same tests as above). Supplementary Figure 1 plots the smoothed histograms of the left-hand 2D:4D for both genders (see Figure 2 in the main text for a comparison with right hands). The linear correlations between the left- and right-hand 2D:4D are 0.657 for the whole sample, 0.658 for men, and 0.646 for women.

7 Figures Demonstrating Censored Distributions

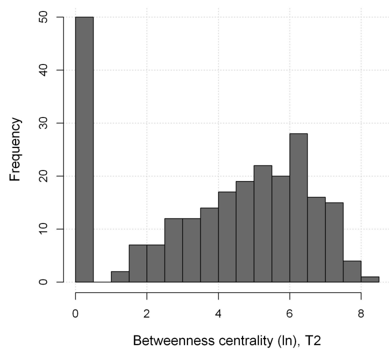
The following three supplementary figures provide a visual illustration of the censored nature of the transitivity and betweenness centrality variables as measures of social integration. As such, these figures provide justification for the use of a tobit model for measuring the relationship between 2D:4D and transitivity and betweenness centrality. Supplementary Figure 2 demonstrates a large accumulation of individuals with zero betweenness (ln). The distribution of transitivity is presented in Figures 3 and 4, with peaks at both zero and one regardless of whether we set observations with less than two connections to zero (Figure 3) or omit them altogether (Figure 4).

8 Robustness Tests

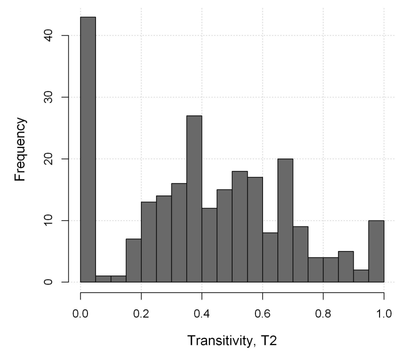
The tables below report several variations of the benchmark models reported in Table 2 of the main text. They are meant to serve as robustness tests to ensure that the results are consistent across model specifications.



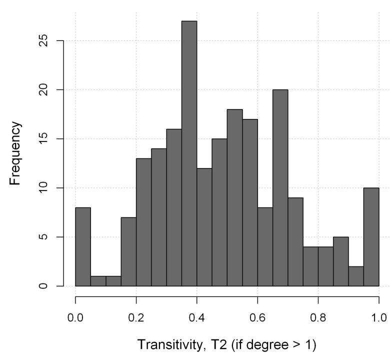
Supplementary Figure 1: The distribution of the left-hand 2D:4D in the sample.



Supplementary Figure 2: The distribution of betweenness centrality at T2 is censored from below by 0



Supplementary Figure 3: The distribution of transitivity at T2 is censored from below by 0 and from above by 1



Supplementary Figure 4: The distribution of transitivity at T2 is censored from below by 0 and from above by 1 even if we only consider individuals with degree larger than 1

Supplementary Tables 2 - 4 show that the estimations in Table 2 in the main text are robust to the estimation technique applied or controlling for local centrality in the estimations corresponding to transitivity and betweenness centrality.

8.1 Controlling for Degree Centrality in Transitivity and Betweenness Models

Supplementary Table 2: Association of 2D:4D with network measures at T2, controlling for local centrality in the regressions corresponding to transitivity and betweenness

	In-degree, T2		Out-degree, T2		Transitivity, T2		Between.(ln), T2	
	Male	Female	Male	Female	Male	Female	Male	Female
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
2D:4D	-.045	-.440**	-.141	.033	.064**	-.037*	-.396**	.255
	(.123)	(.178)	(.096)	(.285)	(.023)	(.019)	(.182)	(.275)
Network, T1	.201*	.140	.068	.238	.117	-.027	.061	.090
	(.116)	(.173)	(.159)	(.206)	(.073)	(.033)	(.046)	(.140)
Degree, T2					-.001	.026	.357**	.472**
					(.006)	(.019)	(.060)	(.046)
Constant					.445**	.264**	1.200**	.234
					(.079)	(.121)	(.465)	(.718)
Obs.	97	79	97	79	97	79	97	79
Pseudo R^2	.007	.018	.002	.010	.439	.101	.168	.167

St. errors robust to heteroscedasticity and clustered at section level.
* p ¡.1, ** p ¡.05; (1-4) ordered logit, (5-8) censored regressions.
Since 2D:4D is sexually dimorphic, 2D:4D normalized separately for men and women.
Network, T1 is the corresponding column variable at T1.

8.2 Simple Linear Regression Models

8.3 Simple Linear Regression Models Controlling for Degree Centrality

8.4 Models Using Network Measures at T1

Supplementary Tables 5 and 6 present estimation results from the same models, however the dependent variables are the network position in the first network elicitation T1 (rather than T2). 2D:4D is never correlated with the T1 position in any of these models, independently of the model specification. This indicates that the network was built between T1 and T2 and allows us to discard the notion that our results are due to previously existing social networks.

Supplementary Table 3: Association of 2D:4D with network measures at T2; simple linear regressions

	In-degree, T2		Out-degree, T2		Transitivity, T2		Between.(ln), T2	
	Male	Female	Male	Female	Male	Female	Male	Female
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
2D:4D	-.221	-.690**	-.121	-.026	.061*	-.037$^{\times}$	-.541*	.026
	(.191)	(.166)	(.338)	(.321)	(.024)	(.017)	(..227)	(.381)
Network, T1	.396	.231	.048	.323	.082	-.018	.154	.089
	(.201)	(.247)	(.260)	(.272)	(.061)	(.042)	(.092)	(.089)
Constant	5.684**	4.935**	6.591**	4.447**	.460**	.466**	4.428**	3.811**
	(.667)	(.355)	(.964)	(.851)	(.040)	(.028)	(.321)	(.625)
Obs.	97	79	97	79	97	79	97	79
R^2	.041	.087	.002	.032	.105	.022	.117	.017

St. errors robust to heteroscedasticity and clustered at section level.
* p <.1, ** p <.05; $^{\times}$p = 0.111; OLS regressions.
Since 2D:4D is sexually dimorphic, 2D:4D normalized separately for men and women.
$Network, T1$ is the corresponding column variable at T1.

Supplementary Table 4: Association of 2D:4D with network measures at T2, controlling for local centrality; simple linear regressions

	In-degree, T2		Out-degree, T2		Transitivity, T2		Between.(ln), T2	
	Male	Female	Male	Female	Male	Female	Male	Female
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
2D:4D	-.221	-.690**	-.121	-.026	.058*	-.032*	-.444*	.222
	(.191)	(.166)	(.338)	(.321)	(.024)	(.013)	(.162)	(.303)
Network, T1	.396	.231	.048	.323	.066	-.003	.076	.080
	(.201)	(.247)	(.260)	(.272)	(.063)	(.028)	(.044)	(.131)
Degree, T2					-.012*	.011	.297**	.383**
					(.005)	(.014)	(.055)	(.043)
Constant	5.684**	4.935**	6.591**	4.447**	.582**	.391**	1.812**	1.080
	(.667)	(.355)	(.964)	(.851)	(.053)	(.088)	(.471)	(.731)
Obs.	97	79	97	79	97	79	97	79
R^2	.041	.087	.002	.032	.159	.044	.472	.438

St. errors robust to heteroscedasticity and clustered at section level.
* p <.1, ** p <.05; OLS regressions.
Since 2D:4D is sexually dimorphic, 2D:4D normalized separately for men and women.
Network, T1 is the corresponding column variable at T1.

Supplementary Table 5: Association of 2D:4D with network measures at T1

	In-degree, T1		Out-degree, T1		Transitivity, T1		Between.(ln), T1	
	Male	Female	Male	Female	Male	Female	Male	Female
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
2D:4D	-.055	-.187	.074	-.065	.035	-.055	.561	-.047
	(.187)	(.191)	(.165)	(.203)	(.121)	(.114)	(.427)	(.379)
Degree, T1					.221**	.156**	1.674**	1.679**
					(.053)	(.057)	(.179)	(.236)
Constant					-.682**	-.361	-3.406**	-3.419**
					(.210)	(.236)	(.808)	(.933)
Obs.	97	79	97	79	97	79	97	79
Pseudo R^2	.000	.003	.001	.000	.108	.054	.146	.193

St. errors (in paretheses) robust to heteroscedasticity.

* p <.1, ** p <.05; (1-4) ordered logit, (5-8) censored regressions.

Since 2D:4D is sexually dimorphic, 2D:4D normalized separately for men and women.

p = 0.324 in (2), p = 0.192 in (7), p >0.63 otherwise for 2D:4D.

8.5 Simple Linear Regression Using Network Measures at T1

Supplementary Table 6: Association of 2D:4D with network measures at T1; simple linear regressions

	In-degree, T1		Out-degree, T1		Transitivity, T1		Between.(ln), T1	
	Male	Female	Male	Female	Male	Female	Male	Female
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
2D:4D	-.014	-.184	.024	.010	.009	-.014	.224	-.006
	(.155)	(.180)	(.160)	(.183)	(.043)	(.044)	(.246)	(.215)
Degree, T1					.057**	.031*	1.003**	1.082**
					(.016)	(.017)	(.092)	(.100)
Constant	1.939**	1.968**	2.001**	1.899**	.123**	.238**	.008**	-.262
	(1.66)	(.186)	(.162)	(.192)	(.053)	(.070)	(.289)	(.325)
Obs.	97	79	97	79	97	79	97	79
R^2	.000	.013	.000	.000	.094	.031	.440	.585

St. errors (in paretheses) robust to heteroscedasticity.
* $p < .1$, ** $p < .05$; OLS regressions.
Since 2D:4D is sexually dimorphic, 2D:4D normalized separately for men and women.
$p = 0.308$ in (2), $p > 0.74$ otherwise for 2D:4D.

8.6 Pooled Estimates for Men and Women

Supplementary Table 7, shows that the results are virtually identical if we pool men and women into one model and include the female dummy, 2D:4D, and their interaction as regressors.

Supplementary Table 7: Association of 2D:4D with network measures at T2; pooled estimations for men and women

	In-degree, T2	Out-degree, T2	Transitivity, T2	Between.(ln), T2
	(1)	(2)	(3)	(4)
2D:4D	-.044	-.145	.060**	-.536* (p = .053)
(normalized)	(.123)	(.101)	(.022)	(.275)
2D:4D × Female	-.347**	.181	-.101**	.591 (p =.132)
	(.170)	(.319)	(.011)	(.391)
Female	-.511**	-.694*	-.021	-.920*
	(.255)	(.382)	(.050)	(.515)
Network, T1	.181**	.132	.079*	.147**
	(.087)	(.162)	(.046)	(.057)
Constant			.438**	4.247**
			(.044)	(.229)
Obs.	176	176	176	176
Pseudo R^2	.015	.013	.114	.022
p-value for females+	.003**	.895	.019**	.876

St. errors robust to heteroscedasticity and clustered at section level.

* p <.1, ** p <.05; (1-2) ordered logit, (3-4) censored regressions.

Since 2D:4D is sexually dimorphic, 2D:4D normalized separately for men and women.

+p-value for female corresponds to testing H^0: 2D:4D + 2D:4D × Female = 0.

Network, T1 is the corresponding column variable at T1.

Supplementary Table 8: Association of 2D:4D and transitivity for individuals with at least two friends

	Transitivity, T2	
	Male	Female
	(1)	(2)
2D:4D	.058**	-.025$^+$
	(.029)	(.026)
Transitivity, T1	.058	.000
	(.050)	(.041)
Constant	.476**	.501**
	(.031)	(.032)
Obs.	92	72
Pseudo R^2	-0.499	.015

St.err. robust to heteroscedasticity and clustered at section level.
* p <.1, ** p <.05; censored regressions, $^+$p = .333.
2D:4D normalized separately for men and women.

8.7 Models Excluding Individuals with Fewer than Two Friends

Supplementary Table 8 reports estimates analogous to Models 5 and 6 in Table 2 from the main text. However, in contrast to Table 2, individuals with fewer than two connections, for whom the clustering is not well defined, are eliminated from the regressions in Supplementary Table 8. As discussed in the main text, the association between transitivity and 2D:4D is robust for men but not women.

References

[1] Brañas-Garza, P., Kovářík, J. & Neyse, L., 2013. Second-to-Fourth Digit Ratio Has a Non-Monotonic Impact on Altruism. PloS ONE, 8(4), pp.1-10.