Organizing effects of Testosterone and economic behavior: not just risk taking *

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Abstract

Recent literature emphasizes the role that testosterone (T), as well as markers indicating early exposure to T and its organizing effect on the brain (such as the ratio of second to fourth finger, $2D : 4D$), have on performance in financial markets (([12]), ([13], [39]). These results may suggest that the main effect of T, either circulating or in fetal exposure, on economic behavior occurs through the increased willingness to take risks. However, Coates et al ([13]) indicate that traders with low digit ratio are not only more profitable, but more able to survive in the long run: so the effect is likely to consist of more than just lower risk aversion. In addition, recent literature suggests a positive correlation between intelligence and higher willingness to take risks (e.g. Burks et al, [9]).

To test these two hypotheses (simple effect on risk attitude, versus a complex effect involving risk attitude and intelligence) we gather data on the three variables, and show that low digit ratio is associated with higher risk taking and higher scores in intelligence tests in men. This explains both the higher performance and higher survival rate observed in traders ([13]), as well as a possible explanation of the observed correlation between intelligence and risk taking in ([9]). This link holds only for men, suggesting a profound gender difference in the way these effects are organized.

We also analyze how much of the total effect of digit ration on risk attitude is direct, and how much is mediated by the effect on intelligence. Mediation Analysis shows that a substantial part of the effect on T on attitude to risk is mediated by intelligence.

Keywords: Risk Attitude, Intelligence, Digit Ratio

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1 Introduction

An important part of our study of human nature is to understand the way in which different traits of individual personality are related and interact with each other, and the biological basis of these traits and their connection. Two important traits that have been recently explored are intelligence and the willingness to take risks: In this paper we explore the connection between these two factors, and biological factors affecting them.

Some biological factors influencing willingness to take risks have been explored: the level of testosterone, both pre-natal and circulating, has been found in several studies as important factor affecting the willingness to take risks. In an experimental study based on an investment game, Apicella et al ([1]; see also Dreber and Hoffman ([16])) found that risk-taking behavior correlates positively with levels of testosterone measured in salivary samples (as well as with level a facial masculinity, as marker of pubertal exposure to T). Willingness to take risks may be generally related to sensation seeking, and biological characteristics associated with this trait have been studied extensively: testosterone is one of the factors that has been associated with it ([35], [39]).

The implications of these effects on real life in addition to experimental behavior may be large and important. For example, in Coates and Herbert ([12]) the level of daily profits in a sample of traders in the London's City has been found to be positively correlated with the deviation from the median level of salivary testosterone of each trader. Similarly in Coates et al ([13]) the level of average profitability over a longer period has been found to be negatively correlated with the ratio of the second to fourth finger ($2D : 4D$ ratio). This ratio (see [27] for an introduction) is considered to be a marker of early (fetal) exposure to testosterone.

A simple explanation relating the willingness to take risks ([1], [16]) with profitability ([12], [13]) is that traders in days with higher level of endogenous T, relative to their own median level, or higher level of prenatal T exposure are simply closer in their behavior to risk neutrality, and therefore choose, relative to other traders, portfolios with higher returns and higher variance. In the long run higher returns of the chosen portfolio insure higher mean profits. But a higher variance in the returns of portfolio implies a higher variance in wealth, or cumulated profits. If a lower bound on losses is imposed (for example, by the limit to total losses by the firm in the sample of traders in [13]), then a trader with higher propensity to risk should also be more likely to cease trading and exit the job; so the survival of these traders would experience larger exit rate and shorter seniority on average. This is what we should expect from theoretical investigations ([6], [7]) of the relationship between attitude to risk and survival in the market: everything else being equal (in particular, given same inter-temporal preferences and beliefs, or information), risk neutral traders are not those most likely to survive market selection. Instead, in

([13]) traders with low digit ratio were also more likely to have a higher seniority, indicating a higher probability of remaining on the job.

A possible explanation for the ability of low digit ratio traders to survive is that the biological factor represented by the marker affects, in addition to risk taking, the general ability of individuals to process information and perform cognitive tasks. Evidence that the $2D : 4D$ ratio affects some cognitive skills is surveyed in ([27], [2]), particularly in the areas of musical ability ([38]), and spatial perception and cognition ([30], [36], [25], [11], [41]), verbal and numerical intelligence ([26]), memory recall ([31]), SNARC effect (Spatial Numerical Association of Response Codes) ([10]). Females affected by Congenital Adrenal Hyperplasia, a condition exposing to high levels of androgens in the womb, scored higher in tests of spatial ability (as Hidden Patterns, Card Rotations, and Mental Rotations: [34]). Recently, several studies ([17], [9], [15]), [5], [19]) have presented evidence that traits that affect economic behavior, like risk aversion, and impatience in choices among payments over time are correlated with several measures of cognitive skills. Specifically for risk aversion, a finding which has been replicated ([9], [19]) is that higher intelligence is broadly associated with higher willingness to take risks, particulary in the gain domain. Intelligence in the population may peak around risk neutrality ([9]).

The hypothesis tested in the study we report is natural: a common biological factor (related to the early exposure to T, and reflected in the digit ratio) influences at the same time intelligence and attitude to risk. We test this hypothesis in a simple experimental design where we gathered information on risk attitude, digit ratio, and intelligence in a sample of males and females. This analysis will allow us to test the relative size of the effects, in addition to the simple existence of a correlation. We can also probe the extent to which the effect of that biological factor influences directly risk attitude, and how much this effect works its way through intelligence. To determine this we will use simple mediation analysis, taking the digit ratio as the independent variable, the risk attitude as the dependent, and intelligence as the mediating one.

2 Experimental Design

A total of 189 subjects participated in the experiment, 73 male. Average age was 22.23 (standard deviation 2.32, mean of 22.54 for male, range of 18 to 31 years).

Intelligence was measured with Raven's Progressive Matrices. The test consists of 60 multiple choice questions originally developed by John C. Raven [33]. In each test item, a candidate is asked to identify the missing item required to complete a larger pattern. The final score is a measure of ability for abstract reasoning and fluid intelligence, that is ability that does not rely on knowledge or skill acquired from experience (as opposed to crystallized intelligence, see [23]).

Attitude to risk was measured through observed choice between random payments, or lotteries. Subjects faced two sets of choice tasks: in both they had to choose between two lotteries. In the first, one of the lotteries had an expected value smaller or equal to the other one's, but smaller variance: we call this lottery "safer". For example, subjects were asked to choose between a payment of 30 euros for sure or a payment of 40 euros with probability 80 per cent. One of the lotteries had a loss as possible outcome; in four out of seven choices, the safer option was a certain amount. Table 1 reports the lotteries given in this task, that we call the lottery choice task. The notation (x, p_1, y, p_2, z) describes the lottery giving the amount x (in euros) with probability p_1, y with probability p_2, and z with the complementary probability $1 - p_1 - p_2$.

Safer lottery	Riskier lottery
(1000, 1)	(2000, 0.5, 0)
(30, 1)	(45, 0.8, 0)
(100, .25, 0)	(130, .2, 0)
(3000, 0.02, 0)	(6000, 0.01, 0)
(0, 1)	(1500, 0.5, -1000)
(50, 1)	(50, 3/6, 200, 1/6, 0)
(50, 3/6, 0)	(200, 1/6, 0)

Table 1: Lotteries presented in the lottery choice task. The lottery in the left column has lower or equal mean as the lottery in the left column, but the variance of the lottery in the right is higher.

The second task is the Holt and Laury (HL) lottery choice task ([21], [22]). Subjects faced a set of nine choices between two lotteries. The set of outcomes of the two lotteries was the same in every choice: one lottery was $(2, p, 1.6)$ (a "safer" lottery"), and the other was $(3.9, p, 0.1)$. The probability p ranged from 0.1 to 0.9 in increments of 0.1, giving nine choices overall. As p increases, the difference in expected utility (for an expected utility decision maker) between the first and second lottery decreases from a positive to negative value. The number of times a subject chooses the first lottery is the measure of his risk aversion provided by this task. We will refer to this task as the HL lottery choice task.

Data on $2D : 4D$ ratio were collected by photo-copy of the hand.

3 Summary statistics and gender differences

A summary description of the main variables of interest shows that our sample is, in all respects, typical. The digit ratio is around 0.96 as typical for a sexually heterogenous population. The ratio is sexually dimorphic, and significantly lower than for women, as expected: see table 2.

	Observations	Mean	Standard Error	[95% CI]
All Subjects	189	0.958	0.0024	[0.953, 0.963]
Male	73	0.950	0.0036	[0.943, 0.957]
Female	116	0.963	0.0032	[0.956, 0.969]

Table 2: Summary statistics for Digit Ratio. Kruskal-Wallis equality-of-populations rank test: $\chi^2 = 4.167, p = 0.0412$. Two-sample Wilcoxon rank-sum (Mann-Whitney) test: $z = 2.043, p = 0.0411$.

The index of intelligence in our sample has also a typical distribution. Out of a total possible score of 60, the mean score in the subjects' pool was 48.9, higher for male subjects than for female subjects by around 3 points. The difference in this sample is statistically significant: see table 3. There is no consensus on this very controversial topic, although the gender differences are usually recognized to be small or insignificant ([20], [24]). A possible explanation for the difference is, as we discuss in the conclusions, the different motivation in the two genders. Size and significance of gender difference in intelligence is not very important for our purposes.

	Observations	Mean	Standard Error	[95% CI]
All Subjects	189	48.931	0.437	[48.076, 49.794]
Male	73	50.797	0.479	[49.840, 51.764]
Female	116	47.758	0.621	[46.527, 48.989]

Table 3: Summary statistics for score in Raven's task. The range in the sample was 12 to 60. Kruskal-Wallis equality-of-populations rank test: $\chi^2 = 9.804, p = 0.0017$. Two-sample Wilcoxon rank-sum (Mann-Whitney) test: $z = -3.139, p = 0.0017$.

As we mentioned, we gathered two measures of risk aversion of the subjects, the lottery choice task and the HL lottery choice task. The Cronbach's α reliability index for the two set of choices combined (16 items) is 0.738; the overall reliability index for the lottery choice task is 0.426. The set of choices in the HL lottery choice task has a higher reliability coefficient: 0.812. This is to be expected: the α grows with the correlation among the scores in different tests, which in the case of the HL lotteries are the choice for a fixed p; for subjects consistency (hence higher correlation among those choices) is more likely when the choices are similar (same outcomes, different probabilities) and presented in an ordered fashion (increasing p).

In the analysis we consider two measures of risk aversion. The first is the number of safe choices in the lottery choice task: we call this the risk aversion measure (RA). The second is the sum of the safe choices in the two choice tasks. We call this variable combined risk aversion measure (CRA). Summary statistics are reported in table 4 (for the risk aversion measure) and 5 (for the combined risk aversion measure).

	Observations	Mean	Standard Error	[95% CI]
All Subjects	189	4.751	0.101	[4.551, 4.951]
Male	73	4.342	0.172	[3.998, 4.686]
Female	116	5.008	0.119	[4.772, 5.244]

Table 4: Summary statistics for risk aversion measure. The range in the sample was 1 to 7. Kruskal-Wallis equality-of-populations rank test: $\chi^2 = 8.976, p = 0.0027$. Two-sample Wilcoxon rank-sum (Mann-Whitney) test: $z = -3.068, p = 0.0022$.

	Observations	Mean	Standard Error	[95% CI]
All Subjects	189	9.417	0.226	[8.971, 9.864]
Male	73	8.876	0.346	[8.186, 9.566]
Female	116	9.758	0.294	[9.175,10.342]

Table 5: Summary statistics for the combined risk aversion measure. The range in the sample was 3 to 16. Kruskal-Wallis equality-of-populations rank test: $\chi^2 = 3.623, p = 0.0557$. Two-sample Wilcoxon rank-sum (Mann-Whitney) test: $z = -1.913, p = 0.0557$.

Female subjects are significantly more risk averse then male, particularly in the risk aversion measure. This is consistent with the findings of a growing literature on the topic (see [14] for a survey of results).

The raw score in the Raven task is usually negatively skewed, and our data are typical in this respect. The score of risk aversion measures (combined and not) are approximately normal. Table 6 reports simple diagnostic tests of the distribution of the variables that are going to be used in the analysis. They suggest the need for non linear transformations of the dependent variables (the Raven score) and independent variable (the digit ratio) in our analysis. We report this check, which does not alter the conclusions.

4 Intelligence, risk attitude, and digits ratio

Two separate strands of the literature have identified a correlation between digit ratio ([39]) and risk attitude on one hand, and intelligence and risk attitude on the other ([9], [15], [5], [17]). In our data set we can test both potential relations, as well as the one between digit ratio and intelligence.

Variable	Pr(Skewness)	Pr(Kurtosis)	χ^2	p-value
Digit ratio (DR)	0.011	0.117	8.15	0.017
Raven Score (I)	0.000	0.000	73.47	0.000
Risk Aversion (RA)	0.087	0.413	3.64	0.162
Combined Risk Aversion (CRA)	0.301	0.040	5.27	0.071

Table 6: Skewness/Kurtosis tests for Normality of the four variables.

Correlation Analysis

The correlation coefficients and their significance are reported in table 7 for the Combined Risk Aversion measure and table 8 for the Risk Aversion measure. The results confirm for male subjects the finding in ([9], [15] and [5]) of a negative correlation between intelligence and both measures of risk aversion; and (consistently with the finding in ([39])) show that subjects with lower digit ratio are more willing to take risks. The correlation between DR and risk aversion, and the correlation between Intelligence and risk aversion do not necessarily imply any correlation between DR and Intelligence: we add to the findings reported in the literature a negative and significant correlation between digit ratio and intelligence in male subjects. The size of this latter correlation is also similar to the other two.

	DR and Intelligence		DR and CRA		CRA and Int.	
All Subjects	–0.074		0.0106		–0.179	**
	(0.308)		*(0.885)*		*(0.013)*	
Male	–0.2629	**	0.240	**	–0.266	**
	(0.0247)		*(0.040)*		*(0.021)*	
Female	–0.0465		–0.145		–0.111	
	(0.620)		*(0.119)*		*(0.231)*	

Table 7: Correlation analysis of Intelligence (measured by the Raven's score), Combined Risk Aversion measure and Digit Ratio. The *, **, *** denote significance (p-value) at the 1 %, 5 % and 10 % level respectively. The entries indicate correlation coefficient, p-value is reported in parenthesis.

As we mentioned, the distribution of the Raven's score is skewed. The skewness in the distribution may be corrected with a Box Cox transform. If we do, the sign of the correlation is unchanged, and its significance improves: for example the significance of the correlation between the Box Cox transform of the Raven and Digit Ratio in males is $p = 0.017$.

The digit ratio is sexually dimorphic, and we have seen to have a strong correlation among males with both intelligence and risk aversion. It is natural to wonder

	Intelligence and DR		DR and RA		Intelligence and RA	
All Subjects	–0.074		–0.029		–0.1764	**
	(0.308)		*(0.692)*		*(0.014)*	
Male	–0.2629	**	0.1049		–0.2866	**
	(0.0247)		*(0.376)*		*(0.013)*	
Female	–0.0465		–0.1881		–0.0595	
	(0.620)		*(0.043)*	**	*(0.524)*	

Table 8: Correlation analysis of Intelligence (measured by the Raven's score), Risk Aversion measure and Digit Ratio.

whether the gender difference in the latter two variables is completely explained by the difference in digit ratio. The regressions of the intelligence score and the risk measures on the gender variables, the digit ratios, and the interaction between the two show (Table 9) that this is not the case.

	Intelligence	Combined RA	RA
	b/p-value	b/p-value	b/p-value
Male	0.468***	–0.148	–0.350**
	(0.002)	*(0.348)*	*(0.024)*
Digit ratio	0.050*	–0.139	–0.165*
	(0.568)	*(0.117)*	*(0.058)*
Male × Digit ratio	–0.250	0.331	0.202
	(0.105)	*(0.038)***	*(0.194)*
Raven score		–0.098	–0.046
		(0.233)	*(0.565)*
Male × Raven Score		–0.203	–0.381
		(0.290)	*(0.043)*
constant	–0.199**	0.114	0.208**
	(0.030)	*(0.224)*	*(0.023)*
N	189	189	189

Table 9: Regressions of Intelligence measured by Raven's score (first column) and the two risk aversion measures (Combined RA and RA, second and third column respectively) on several regressors. All variables (except male) are normalized to have zero mean and unit standard deviation.

For intelligence, the variable *Male*, equal to one for male subjects, is significant even when digit ratio is among the independent variables; for the risk aversion measure, the variable *Male* and the interaction of the gender variable with the intelligence score are both significant. These findings suggests a complex relation between our three main variables and the gender, that we will now try to unravel.

Mediation Analysis

Our correlation analysis shows that two factors may potentially affect the attitude to risk: one is described by a biological marker, digit ratio, and the other is the intelligence of the individual. If we want to compare the relative strength and significance of the two, we can run a regression of our measure of the risk attitude on both variables. To make the size of the estimated coefficients comparable, we first normalize all the variables to mean zero and unit standard deviation. The result of the regression of the risk aversion measure on these normalized variables is reported in the last column of table 10 for male subjects, and table 11 for female subjects. In the regression for male subjects, the coefficient of digit ratio is 0.036, (p-value $=$ 0.791); the coefficient of intelligence is -0.427 (p-value $= 0.021$). For female subjects, we observe a different pattern: the coefficient of digit ratio is -0.165, (p-value $=$ 0.047); the coefficient of intelligence is -0.046 (p-value $= 0.546$).

This simple model does not consider the possibility that the effect of digit ratio may occur both directly on risk attitude, and indirectly through its effect on intelligence. We have reason to consider this hypothesis in view of the correlations reported in the tables 7 and 8, which suggest that intelligence might act as mediating variable between the biological factors represented by digit ratio and risk aversion. It is also reasonable to take the biological factors as independent variable, determining the others, since they are fixed at birth.

A systematic way of testing this hypothesis is through mediation analysis ([3], [4], [28], [29], [32]). The model we consider is simple mediation, and is illustrated in Figure 1, where we estimates reported are for male subjects. In this figure the three circles represent the variables we are considering and the arrows indicate the direction of causality. DR may influence risk aversion directly, or through the path passing through intelligence. Mediation analysis tries to determine the size of the direct and mediated effect.

Simple mediation analysis is performed in two steps. In the first step we estimate three regressions among an independent variable (DR, digit ratio in our case), a dependent variable (RA, risk aversion in our case), and a mediating variable (I, intelligence as measured by Raven's score). The mediating variable is influenced (in a causal sense) by the independent variable and in turn influences the dependent one. The three regressions are:

$$RA = \alpha_1 + bI + c'DR + error \tag{1}$$

$$I = \alpha_2 + aDR + error \tag{2}$$

$$RA = \alpha_3 + cDR + error \tag{3}$$

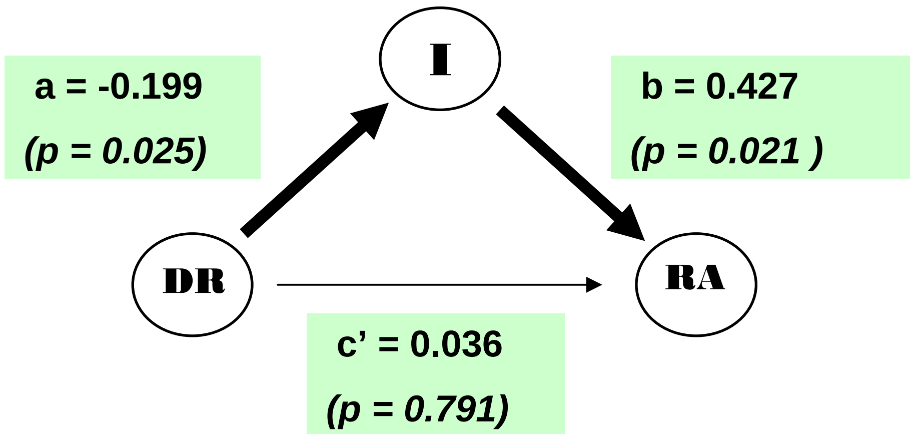

Figure 1: Mediation analysis of the effect of digit ratio (DR), direct and mediated by intelligence (Intelligence (I)), on Risk Aversion (RA, risk aversion measure). The coefficients and p-values reported in the figure refer to the Raven's score as measure of Intelligence, and number of safer choices made in the lottery choice task, for male subjects: see Table 10 for details.

The regression of risk aversion on intelligence and digit ratio gives an estimate of the coefficients b and c' (equation 1). The result of this in the case of male subjects and Risk Aversion measure are reported in the last column of table 10. We then separately estimate the coefficient a, regressing our measure of intelligence on digit ratio (equation 2). The results are reported in the second column of table 10. The product of the two coefficients a (which estimates the effect on Intelligence of DR) and b (which estimates the effect on risk aversion of Intelligence) gives the size of the indirect (mediated by intelligence) effect of digit ratio on risk attitude. The coefficient c' estimates the direct effect of digit ratio on risk aversion, when we are also conditioning on the indirect effect from Intelligence.

In the second step we estimate the significance of the direct and indirect effects. The ratio of the product ab (indirect effect) over the sum $ab + c'$ (direct and indirect effect) gives a measure of the fraction of the effect mediated by intelligence. The Sobel-Goodman (SG) statistic ([18], [37]) tests the hypothesis that the product ab of estimated coefficients is different from 0. The Sobel statistics is derived by approximating the standard error of the product of the estimated a and b using a Taylor's series expansion, and is correct under the assumption that the product is normally distributed as the sample size becomes large. This assumption however is unlikely to hold when the null hypothesis that $ab = 0$ is not true. Recently, Bollen and Stine ([8], see also [40]) proposed to estimate asymmetric confidence intervals of the product ab using bootstrapping methods. In our case the two methods give very similar estimates of the confidence intervals and the significance of the product.

Table 10 reports the regressions necessary for the in the case of male subjects, for the risk aversion measure. The percentage of the total effect that is mediated by the intelligence is 69.6% (Sobel-Goodman test: p-value = 0.0844).

	Risk Aversion on DR	Intelligence on DR	RA on DR and Int.
	b/p-value	b/p-value	b/p-value
Digit ratio	0.122	–0.199**	0.036
	(0.377)	*(0.025)*	*(0.791)*
Raven's score			–0.427**
			(0.021)
constant	–0.257**	0.269***	–0.142
	(0.048)	*(0.001)*	*(0.290)*
N	73	73	73

Table 10: Mediation Analysis of the effect of digit ratio on risk attitude in male subjects. The risk attitude measure is the Risk Aversion measure. The mediating variable is Intelligence, measured by Raven's score. All variables are normalized to mean zero and unit standard deviation.

Table 11 reports the same results in the case of female subjects. The percentage of the total effect that is mediated by intelligence is 1.38% (Sobel-Goodman test: p-value = 0.812).

	Risk Aversion on DR	Intelligence on DR	RA on DR and Int.
	b/p-value	b/p-value	b/p-value
Digit ratio	–0.168**	0.050	–0.165**
	(0.043)	*(0.620)*	*(0.047)*
Raven's score			–0.046
			(0.546)
constant	0.218**	–0.199*	0.208**
	(0.012)	*(0.060)*	*(0.018)*
N	116	116	116

Table 11: Mediation Analysis of the effect of digit ratio on risk attitude in female subjects. See table 10 for details.

The pattern is consistent with the one we have just seen in the case of the Combined Risk Aversion measure. Table 12 reports the result for male subjects, and and table 13 for females.

We may conclude that a substantial part of the effect of digit ratio on risk attitude is mediated in male subjects by its effect on intelligence. As we should expect, the mediation does not occur for female subjects, because there is no effect form DR on risk aversion in the first place, as tables 7 and 8 have shown.

	Combined RA on DR	Intelligence on DR	Comb.d RA on DR and Int.
	b/p-value	b/p-value	b/p-value
Digit ratio	0.252**	–0.199**	0.191
	(0.041)	*(0.025)*	*(0.124)*
Raven's score			–0.301*
			(0.067)
constant	–0.115	0.269***	–0.034
	(0.309)	*(0.001)*	*(0.774)*
N	73	73	73

Table 12: Mediation Analysis of the effect of digit ratio on risk attitude in male subjects. The risk attitude measure is the Combined Risk Aversion measure. The mediating variable is intelligence, measured by Raven's score. All variables are normalized to mean zero and unit standard deviation.

	Combined RA on DR	Intelligence on DR	Comb.d RA on DR and Int.
	b/p-value	b/p-value	b/p-value
Digit ratio	–0.144	0.050	–0.139
	(0.119)	*(0.620)*	*(0.132)*
Raven's score			–0.098
			(0.251)
constant	0.133	–0.199	0.114
	(0.165)	*(0.060)*	*(0.242)*
N	116	116	116

Table 13: Mediation Analysis of the effect of digit ratio on risk attitude in female subjects. See Table 12 for details.

5 Conclusions

We have reported four main findings. Let us first consider male subjects. Our first finding is that in male subjects the $2D : 4D$ digit ratio is significantly correlated both with intelligence and attitude to risk aversion. The correlation of digit ratio is negative and significant for intelligence. If we use our combined measure of risk aversion, the correlation is positive and significant for risk aversion. For both intelligence and combined risk aversion the correlation is around 0.25 in size, and significant at better than 5 per cent level ($p = 0.024$ for intelligence and $p = 0.04$ for the combined measure of risk aversion). Intelligence and combined risk aversion are also negatively correlated in male subjects, higher intelligence associated with lower willingness to take risks; the size effect is 0.26 ($p = 0.021$).

Let us now turn to female subjects. Our second finding is that in this case these correlations are not significant. In the case of the risk aversion measure derived from lottery choice, the correlation between digit ratio and risk attitude is significant but *negative*: that is, higher ratio is associated with smaller risk aversion, the opposite of what we found in male subjects for the combined measure of risk aversion.

The raw correlation results are easier to interpret in light of simple mediation analysis, if we take digit ratio as the independent, risk aversion as dependent, and intelligence as mediating variable. The analysis tried determines how much of the total effect of biological factors expressed in the digit ratio affect the risk attitude directly, and how much indirectly through the effect on intelligence.

Our third finding is that in male subjects a substantial part of the effect of digit ratio on risk attitude is mediated by the effect on intelligence. The precise extent of this effect varies depending on the measure of risk attitude that is being used, and is between 30 and 70 per cent. The final and fourth finding is that this mediation effect is absent in females. In summary, it appears that the mechanism of transmission between biological features represented by the digit ratio marker are substantially different in males and females. This conclusion is supported by our analysis of the effect, in the entire sample, of digit ratio and the interaction with gender on intelligence and risk aversion (table 9).

These findings help to explain one of the initial puzzles: how do low digit ratio traders survive ([13]) in the market? Our results indicate that individuals with low digit ratio are at the same time more inclined to take risks, and more effective in information processing. This joint effect would contribute to explain the higher profitability (in addition to the effect on risk attitude) as well as the ability to survive due to a better discrimination in the choice of investment strategies.

A word of caution is obvious but necessary: we measured intelligence with a test, and performance in a test is the joint outcome of at least two factors: skill and effort. A high score in an intelligence test induces motivation in subjects that can differ systematically across genders and subjects with different digit ratio: for example, if male subjects with lower digit ratio are also more sensitive to inter-personal comparisons of outcomes, this motivation would systematically affect the effort component, making the observed performance of these subjects systematically better, even in absence of differences in intellectual skill. In our experiments, the score in the Raven test was privately announced to single subjects one month after the test, so it is unlikely that the motivation to excel in public, compared to others, played a significant role. This feature of the experimental design does not yet preclude the possibility that an internal motivation, independently of the observability of the relative outcome, played some role; although overall the effect is likely to be modest. Separating the effect on skill and motivation of the biological factors represented by the digit ratio seems the next step in the research agenda.

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