# Do testosterone levels in females have influence on the distrust game, the beauty contest game, and risk-aversion?

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**Abstract** One of the famous neuroscientific studies on economic decision makings on the *American Economics Review* is Zak *et al.* (2005), which reported that male (but not female) players who received high distrust signals from opponent players showed higher dehydro-testosterone levels. We measured testosterone levels in this study since dehydro-testosterone is produced from testosterone by the enzyme 5-α reductase. Using female college students, we found that (1) there was no relation between distrust signals and the receivers' testosterone levels, as was reported in Zak *et al.* (2) female players with higher testosterone levels had lower values in the beauty contest game, i.e., they were more conscious about others' strategies, (3) there was positive but not significant relation between testosterone levels and risk aversion, which is contrary to our initial prediction.

Keywords: testosterone, trust-game, beauty-contest, risk-aversion,

## 1. Introduction

Many researchers from different academic areas are trying to understand the mechanism by which various kinds of hormones and neurotransmitters affect human decision making. Since hormones mediate the coordination of the whole body, they are considered to influence on many social behaviors.

In this study, we have focused on the relationship between testosterone and economic decision-making, using only female subjects. We performed three kinds of experiments. The first involved the distrust-game, or trust game, which we will explain later in detail. We investigated whether subjects experienced a change in their testosterone level when they received a distrust signal. Zak, *et al*., reported that dehydro-testosterone (DHT) levels of male subjects, but not female subjects, increased after they received distrust signals. Testosterone levels also did not change significantly. We tried to replicate the study but with testosterone, which is a precursor of DHT.

Our second type of experiment involved the so-called beauty contest game. In this game, subjects are asked to choose one number between 1 and 100, to indicate a number as close as possible to the one that is obtained by multiplying the average of the numbers chosen by all the players by 0.7. For example, suppose that all subjects

first choose an arbitrary numbers and the average is 50. In this case, the right answer is 35. If all subjects are rational enough to predict the choices of all participants, then the right number becomes about 25 after the second iteration, and with successive iteration it eventually reaches 1. We had predicted that higher the subject's testosterone level, more aggressive they would be in this sort of competitive situation, and accordingly, those with higher testosterone level would answer smaller numbers.

In order to outperform other subjects, the player needs to think about the multiplication operation on the average of all chosen numbers, which leads to smaller number being the right answer. In some context, this game measures how rational an agent is. In our experiment, however, we used this game to measure the competitive attitudes of subjects with higher or lower testosterone levels.

The third type of experiment concerned the relationship between the level of testosterone and the degree of risk-aversion. The latter was obtained by asking the subject's preference between a probabilistic (ordinary) lot and a certainty lot, the expected values of which were the same. Then, subjects were asked the certainty equivalence of the first lot. The questions we used were taken from Kahneman and Tversky (1979).

Our prediction for this experiment was a negative correlation between the level of testosterone and the degree of risk-aversion, *i.e.*, higher the testosterone level, the less risk-averse the person would be. The reasoning behind this prediction was simply that, since testosterone is regarded to cause aggressive behavior particularly in men, a higher testosterone level should make the individual more risk-taking, or risk-loving. This is in accord with the widely known observation that men are more risk-loving than women.

Let us examine the topics addressed by these three experiments in turn.

## 1. Testosterone and distrust signals

The trust game is as follows (Berg *et al*. 1995; Fershtman and Gneezy 2001): there are two decision makers, DM1, and DM2, who do not know each other throughout the game. DM1 is given $10 at the beginning of the game, who then sends some proportion out of this $10 to DM2. To make it concrete, let us suppose that DM1 sends $5 to DM2 and retains $5. DM2 receives the amount sent by DM1 multiplied by three, which amounts to $15 in this case. Of this amount, DM2 decides how much money to send back to DM1. Let us suppose that DM2 sends back $4 to DM1.

Accordingly, DM1 finishes the game with the sum of the retained money in the first stage plus the amount that DM2 sends back to DM1. In our example, DM1 gets

$5 plus $4 = $9 and DM2 gets $11.

This game is called the trust game, or the distrust game, because if DM1 were to trust DM2 and send DM2 the whole $10, this would maximize the sums of money received by both DM1 and DM2, but this in turn gives a chance for DM2 to retain the whole amount of money received and DM1 would finish the game with no money at all. This situation can be seen as complete betrayal. However, if DM2 is fair enough, he/she may send back an amount such that both DM1 and DM2 end up with the same amount. When this is the case, DM1 can trust DM2 completely and send the whole $10. DM2 in turn, would send back half of the whole $30 and two players each finish with $15.

On the other hand, DM1 may retain the whole $10 and send nothing to DM2. This decision will leave DM1 with $10 for sure but no possibility finishing with more than $10. In this case, DM1 sends no money and a signal of complete distrust to DM2.

Using this experimental scheme, Zak *et al*. found that when DM2 received a relatively small amount of money, a higher DHT level was observed in case of male subjects but not female. DHT is produced from the testosterone by the enzyme 5-α reductase and the former is estimated to be roughly 3-fold more potent than the latter. Therefore, the results of Zak *et al*. imply that, men tend to become more aggressive when they are distrusted.

We tried to replicate this observation using female subjects. With measurement of their testosterone levels, we expected to find a significant change in DM2's hormonal level confronting distrust signals. The initial endowment for DM1 $10 was 1000 yen, which was about 10% less than $10 (about $1 = 110 yen on the date of the experiment June 13 2008). To further follow Zak *et al*. (2005), we divided DM2s into three groups. One of these was the control group who received a randomly assigned amount from 0 to 3000 yen which did not reflect DM1's decision at all and this situation was made known to both DM1 and DM2 before the experiment. The other two-thirds of the whole group constituted the experimental group; this group was divided according to the amount of money sent by DM1 into, they are divided to a trusted group, members of which received equal to or more than 1500 yen, and the distrusted group, members of which received less than 1500 yen.

We took a saliva specimen before the experiment and a second specimen shortly after DM2s were informed of the amount of money their corresponding DM1s would pass to them. As described above, our focus was on the change in testosterone level after DM2s received the trust or distrust information.

The results were not clearly in any particular direction. The mean testosterone levels were in the order: distrusted group < trusted group < controlled group. When we compared the trusted and distrusted groups, we observed a very weak positive

correlation, i.e., the more trust was shown in a person, the more testosterone was secreted by them. Using the two-sample one-tailed t-test assuming identical variance, the t-statistic for the relation was -0.5147 with a p-value of 0.3069. Since the number of experiments we performed was 17, it may be the case that there were too few samples to produce any significant statistics.

Comparing the control and the trusted groups, the difference was now statistically significant in that the controlled group secreted more testosterone than the distrusted group. Using the two-sample one-tailed t-test assuming identical variance, the t-statistic was -1.8806 with a p-value of 0.04049. We obtained similar results using the Welch two-sample t-test. The number of observations in this case was 15. We also predicted that DM1s with a high testosterone level would tend to distrust others and send a smaller amount of money. However we found no significant relationship in accord with this conjecture.

We do not have a good explanation for these results. In particular we have no satisfactory explanation for the high testosterone level being found in the controlled group. Therefore, we conclude that there is not a clear relation between distrust signals and the level of testosterone secretion. Our results may be related to the small sample size of the experiment, or may indicate the nonexistence of the relationship in case of women.

## 2. Testosterone and the beauty-contest game

As is widely known, John Maynard Keynes pointed out the resemblance of the beauty-contest game to the psychology of the market. In this game settings, the correct predictor of the winner of the contest becomes the winner of the game. Players of the game have to consider not only their own opinion who is most beautiful, but also others' preferences. Therefore, the winner is rather the person who best predicts other players' actions after taking their predicted preferences into consideration.

A typical game of this kind proceeds as follows: each player chooses one number between 1 and 100. The winner of the game is the player, who picks the number closest to the value obtained by multiplying the average picked by all players by 0.7. The only logical answer should be 1, since the average of the numbers (A) is multiplied by 0.7, and 0.7A therefore becomes the right answer. If all players fully understand this, all of them will think that the other players will reduce their initial choice of numbers by the factor 0.7. This process continues until all players reach the conclusion that the right answer of the game should always be 1 regardless of the initial preferences, at least logically.

However, this is not the case, as is easily predicted by most people except game

theorists. Actual players do not think so deeply the first time they play the game, or at least they do not correctly think that all other players behave in this extremely logical manner. Therefore the real problem is how many times they should multiply the initially conjectured average A=50 by 0.7. Typically, many players chose the number 35 in this setting, which implies that they do the multiplication only once. Another typical, but less popular number is 25, which is obtained by 50 times 0.7 squared. It has also been reported that the more times a subject takes part in this experiment, the right answer becomes smaller (Nagel 1995; Stahl 1996)).

In our experiment, we focused on the influence of testosterone level on the number predicted by the participants. Our simple guess was that, the higher the level of testosterone, the smaller the predicted number would be; i.e., a relatively high testosterone level would make the player more willing to win in this kind of competitive situations.

Our results seem to support this supposition. We used the beauty-contest game twice; the first time the award given to the four best subjects was 1000 yen (about $10). From the first experiment, we obtained an insignificant negative relationship between the level of testosterone and the number picked by the players. The p-value was 0.153 and the adjusted $R^2$ value was 0.0448 for 26 observations. As the subjects became accustomed to the rules of the game, we obtained a significant relationship from the second experiment, in which the five closest predictors received 600 yen (about $6). The p-value was 0.0287 and the adjusted $R^2$ value was 0.139 with 28 subjects[1].

We interpret these results as indicating that testosterone makes an individual more eager, and more serious in thinking about others' predictions and perform more number of iterations in order to get the right number to in competitive situations such as this.

Coates and Herbert (2008) reported that testosterone may be an important factor in competitive security-traders in the City of London. Together with our findings in female subjects, this advantage of a higher testosterone level may apply to any extremely competitive markets, such as stock, securities, and foreign exchange markets.

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[1] To assure that our experiment had a procedural accuracy, we omitted observations with the two measured values of the same saliva sample are mutually different for more than 25%.

## 3. Testosterone and risk-aversion

Since testosterone makes the male body masculine and makes men more aggressive, it is reasonable to expect that an individual with a higher testosterone level will be less risk-averse, or more risk-loving than other individuals. This is consistent with the observation that men are generally more risk-loving than women.

First, we asked subjects which lot they preferred: 1. a lot consisting of 80% chance to win 4000 yen (about $40), and 20% chance to win 0 yen, or 2. a lot winning 3000 yen ($30) for sure. Then, for those subjects who preferred the second of these options, we asked, assuming that they could change the amount under the second option, how much money is the lower bound to choose the first lot, i.e., we asked the certainty equivalence of the first lot.

Among 47 subjects, 42 chose the second option, and the remaining 5 chose the first. We regressed the amount of money they designated as the critical value on their levels of testosterone. Our initial guess was that there would be a positive correlation between these two values.

Although we expected a positive and significant correlation, we found a negative but non-insignificant relationship. Data of the 47 subjects showed a slightly negative relationship with a p-value of 0.5132. Our conclusion from this experiment showed that higher testosterone levels do not affect the degree of risk-aversion in women. Although this is not in accord with our initial conjecture, it does replicate the results of Zak *et al*. (2005). It is possible that, with regard to risk-taking behaviors, men are influenced by testosterone as it might be expected, but this is not the case for women.

Apicella *et al*. (2008) found a positive correlation between men's testosterone level and their degree of risk-loving. It has not yet been established that this kind of relationship is not applicable to women, as suggested by the results of the present study and those of Zak *et al*. (2005).

## 4. Discussion and further research

Following Zak *et al*. (2005), we conjectured that the higher testosterone level caused by distrust signals might occur in women as well as in men, but this was not the case. This might well show that men and women show different responses to various kinds of social signals, including trust.

With regard to the trust signals and testosterone levels, Burnham (2007) reported that men with higher testosterone levels tended to reject unfair offers in the ultimatum game. As he suggested, men may think of distrust signals as similar to aggression directed at them, which may be why men with higher testosterone levels

reject offers in the ultimatum game and why distrust signals increase male DHT levels.

Our results showed that women with relatively high testosterone levels tended to choose lower numbers in the beauty-contest game. Perhaps this was because women with higher testosterone levels think more seriously about how others think and take it into consideration in a competitive situation such as in this game. To test this hypotheses, we plan to investigate whether the same is true for men in our next experiment.

Although we did not find a significant relationship between testosterone levels and risk-aversion, Apicella *et al*. (2008) reported a negative relationship between them in men. Therefore, it is desirable to replicate our experiment with male subjects to see if our present results are consistent with those of Apicella *et al*. (2008).

Coates and Herbert (2008) suggest that higher testosterone levels in traders are associated with higher profits in the securities market. This is somewhat puzzling to academic economists since although a higher testosterone level may well lead to riskier transactions, it does not necessarily mean higher profits. The result of Coates and Herbert may have been related to a higher risk-premium, or coincidentally their experiment may have been performed during a bull period.

We have just begun to investigate hormonal influences on the economics of decision-making. There is a wide variety of knowledge to be further investigated and integrated in the future.

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