SUPPLEMENTARY ONLINE MATERIAL FOR

Heritability of Cooperative Behavior in the Trust Game

David Cesarini, Christopher T. Dawes, James H. Fowler, Magnus Johannesson, Paul Lichtenstein, Björn Wallace. *Proceedings of the National Academy of Sciences* 105 (10): 3721-3726 (11 March 2008)

Methods

Researchers have increasingly used Bayesian methods, implemented using Markov Chain Monte Carlo (MCMC) algorithms, to estimate the variance components in ACE models. The likelihood functions in genetic models often present computational challenges for maximum likelihood approaches because they contain high-dimension integrals that cannot be evaluated in closed form and thus must be evaluated numerically (1). MCMC algorithms evaluate the integrals using random draws rather than evaluating them analytically. Recent studies have successfully applied Bayesian methods to genetic models using binary data (1, 2), survival analysis (3), nonlinear developmental change and GxE interaction (4), item response theory (5), longitudinal models (6), and multivariate models for ordinal data (1). For a detailed discussion of Bayesian ACE models, readers should refer to van den Berg, Beem, and Boomsma (1).

The ACE model can be specified as a mixed-effects censored linear regression model, or tobit model, where subject j is a member of family i choosing to send or return some fraction of their total endowment to the other player in the game. The model is defined as:

$$y_{ij}^* = \mu + \chi_{ij}$$

where the y_{ij}^* is a latent variable that cannot be observed for values below zero and above one, μ is the population mean, and χ_{ij} is the sum of genetic, shared environment, unshared environment random effects.

The observed censored variable y_{ij} is defined as:

$$y_{ij} = 0 \text{ if } y_{ij}^* \le 0,$$
$$y_{ij} = y_{ij}^* \text{ if } 0 < y_{ij}^* < 1,$$
$$y_{ij} = 1 \text{ if } y_{ij}^* \ge 1$$

This model incorporates the fact that subjects in the trust game are only allowed to send as much as all of their initial endowment and as little as none of their initial endowment to their counterpart. As a result, the amount we observe them send or return is censored from below at zero and above at one. For example, subjects may want to send more than their endowment but are not able to do so given the way the trust game is constructed.

For MZ twins χ_{ij} is the sum of three random effects:

$$\chi_{ij}^{MZ} = A_i + C_i + E_{ij}$$

where A_i is the family genetic factor, C_i is the family shared environment factor, and E_{ij} is the individually-experienced unshared environment factor. For DZ twins χ_{ij} is a function of four random effects variables:

$$\chi_{ij}^{DZ} = A_{1i} + A_{2ij} + C_i + E_{ij}$$

where A_{1i} is the family genetic factor shared by both twins, A_{2ij} is the individually-inherited genetic factor that is unique to each twin, and C_i and E_{ij} are the same as for MZ twins.

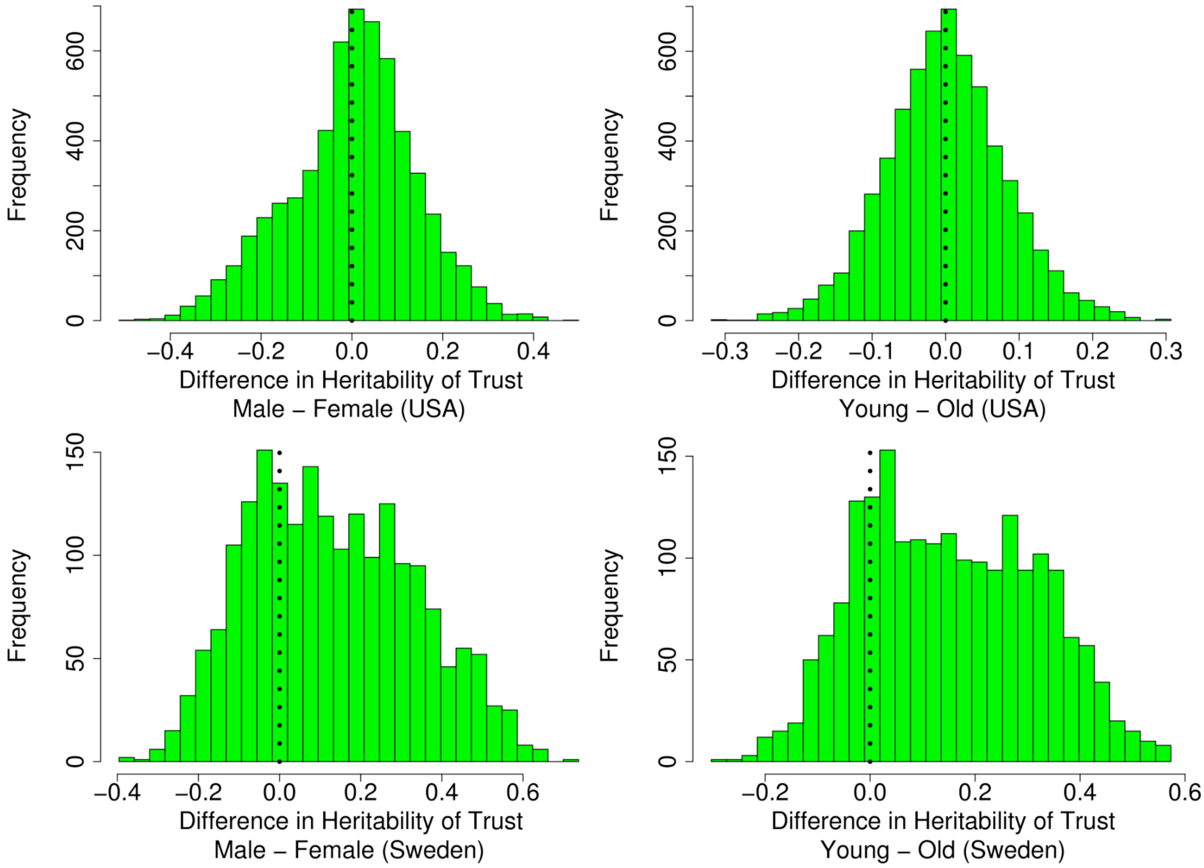
Replicating the methods used in this literature, we assume that our unobserved random effects are normally distributed: $A \sim N\left(0,\sigma_A^2\right)$, $A_1 \sim N\left(0,\sigma_A^2/2\right)$, $A_2 \sim N\left(0,\sigma_A^2/2\right)$, $C \sim N\left(0,\sigma_C^2\right)$, and $E \sim N\left(0,\sigma_E^2\right)$. Notice that the variance of A_1, the family genetic effect for DZ twins, is fixed to be half the variance of A, the family genetic effect for MZ twins, reflecting the fact that MZ twins on average share twice as many genes as DZ twins. Moreover, DZ twins are also influenced by individually-specific genes A_2 that are drawn from the same distribution as the shared genes since on average half their genes are shared and half are not. These assumptions about the genetic variance help to distinguish shared genes from the shared environment variable C that is assumed to have the same variance for both MZ and DZ twin families, and the residual unshared environment variable E from which a unique draw is made for each individual.

We then use the variances of the random effects to generate estimates for the influence of heritability $h^2 = \sigma_A^2 / (\sigma_A^2 + \sigma_C^2 + \sigma_E^2)$, common environment $c^2 = \sigma_C^2 / (\sigma_A^2 + \sigma_C^2 + \sigma_E^2)$, and the unshared environment $e^2 = \sigma_E^2 / (\sigma_A^2 + \sigma_C^2 + \sigma_E^2)$. Since the underlying components are not constrained, the estimated proportions can range anywhere between 0 (the component has no effect on variance) and 1 (the component is solely responsible for all observed variance). In principle, it would be possible to test for gene-environment interactions using this setup, by investigating whether heritability varies, possibly non-linearly, by social stratum or some other background variable (7). In practice, however, the power to detect such interactions is very low in a sample size such as ours, and hence we do not pursue this.

We estimated three types of models in addition to the ACE model. The AE model accounts for only heritability and common environment, a CE model accounts for only common and unshared environment, and an E model accounts for only unshared environment. Procedurally, the difference between the ACE and these sub-models is that one or more variances are not estimated. For example, in the AE model the random effect for the common environment is not estimated and $\sigma_C^2 = 0$. To compare the fit of ACE, AE, CE, and E models we used the deviance information criterion (DIC), a Bayesian method for model comparison analogous to the Akaike Information Criterion (AIC) in maximum likelihood estimation. Models with smaller DIC are considered to have the best out of sample predictive power (8). The DIC penalizes models for deviance (Dbar), which captures model fit, and the effective number of parameters (pD), which captures model complexity.

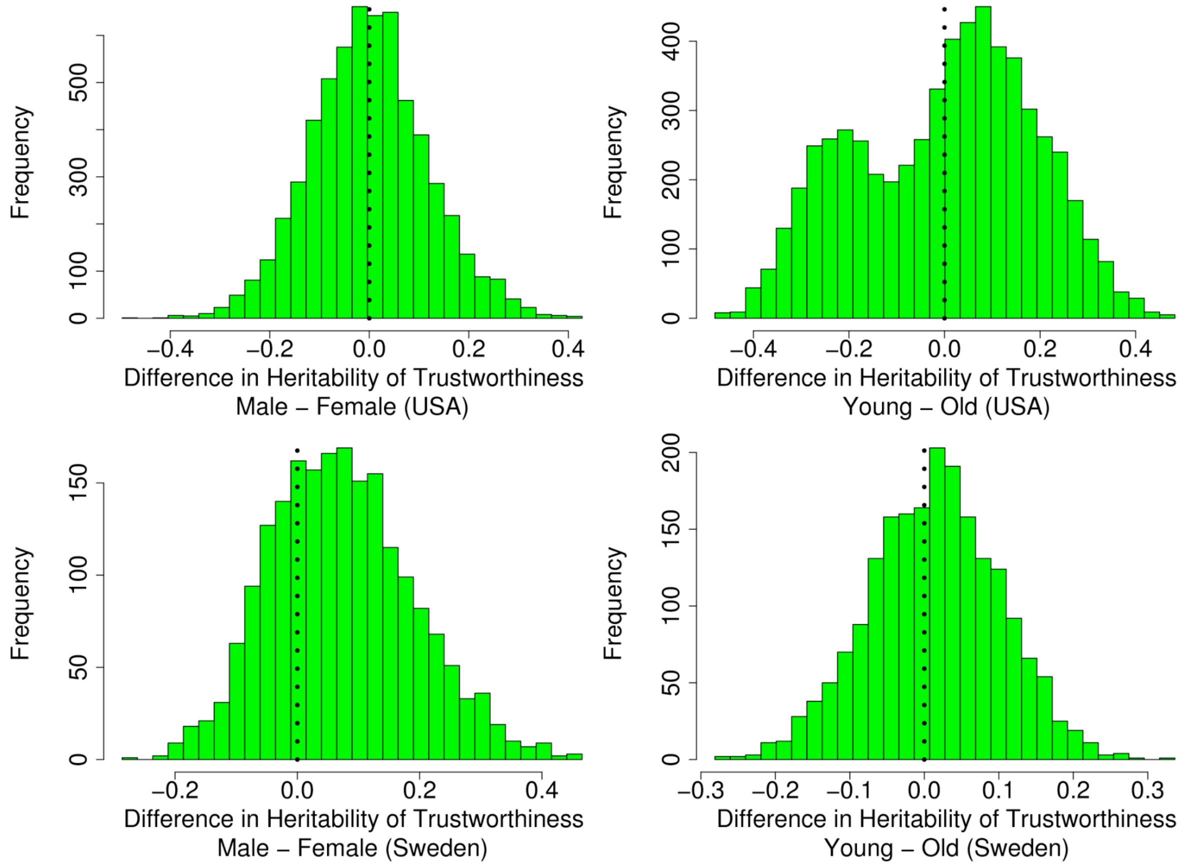
In our MCMC procedure we use vague, or flat, prior distributions to ensure they do not drive model results. For μ we use a mean-zero normal distribution with variance 1,000 and for the precision parameters associated with σ^2_A, σ^2_C, and σ^2_E we use a gamma with shape parameters 0.01 and scale parameter 100. In addition, we use convergence diagnostics to be sure we have reached the stationary posterior distribution. To ensure that the models converged to their target posterior distribution, we began sampling from the joint posterior distribution after convergence was established using the Brooks and Gelman (9) statistic (values of less than 1.1 on each parameter indicate convergence). For all of the models the “burn-in” period was 100,000 iterations and the chains were thinned by 100 for the posterior sample.

Figure S1. Test of Differences in Heritability of Trust by Gender and Age



Note: These results show that we found no significant differences in heritability of trust by age or gender. Each panel shows the results of an ACE model that separately estimates A, C, and E variance components for men and women (left panels) or for below median age (young) and above median age (old) subjects (right panels). Top panels are from models estimated on the USA sample and bottom samples are from models estimated on Sweden sample. The histograms show the posterior distribution of the difference in heritability (h2) between men and women or between young and old subjects. The mode of each distribution is close to zero, and the histograms show a substantial number of posterior draws on both sides of zero, suggesting that the hypothesis that age or gender influence heritability is not credible for these samples.

Figure S2. Test of Differences in Heritability of Trustworthiness by Gender and Age



Note: These results show that we found no significant differences in heritability of trustworthiness by age or gender. Each panel shows the results of an ACE model that separately estimates A, C, and E variance components for men and women (left panels) or for below median age (young) and above median age (old) subjects (right panels). Top panels are from models estimated on the USA sample and bottom samples are from models estimated on Sweden sample. The histograms show the posterior distribution of the difference in heritability (h2) between men and women or between young and old subjects. The mode of each distribution is close to zero, and the histograms show a substantial number of posterior draws on both sides of zero, suggesting that the hypothesis that age or gender influence heritability is not credible for these samples.

Sweden Experiment Procedures

The ethics committee for medical research in Stockholm approved the study and the recruitment of subjects.

Subjects were told not to talk to each other during the experiment and to raise their hands if they had any clarifying questions during the experiment (such questions were rare and were answered in private). They were also told about the strong norm against deception in experimental work in economics. They also filled out a form with information about their bank account for administering the payments in the study. They were then given the instructions for the first game. Decisions in the experiments were not made under time constraint. When all subjects had completed the first experiment, instructions were handed out for the second experiment, and so on. In total subjects participated in five different experiments. This was followed by a short questionnaire with survey questions and a personality test and a cognitive ability test. The personality test and the test of cognitive ability have both been developed by Assessio International. The personality test is designed to measure four of the factors in the five factor model of personality (11). Subjects took the test without a time constraint. The test of cognitive ability uses subset of questions from a more comprehensive IQ test developed in Sweden in the 1960s. Subjects had twenty minutes to complete the three sections on analytical, logical and numerical reasoning.

On average the experimental session lasted a little bit over an hour and average earnings were SEK 325 (exchange rate; $1 is about SEK 7).

Instructions to Investors, Sweden Experiment

In this section you have been randomly paired with another participant in this study (but nobody in this room and nobody from a previous question). You will not find out who this person is, nor will he or she find out who you are, not now, nor after the experiment is over.

You have been assigned 50 SEK, and your task is to decide what share of the 50 SEK to transfer to the person in the other room (not the same person as in any of the previous questions and nobody in this room). The money you give to your partner is tripled; in other words, for every 10 SEK you decide to transfer, your partner receives 30. The partner will then decide how much of the (tripled) money to return to you. You will then earn whatever money is returned to you plus the share of the 50 SEK you decided to keep.

To assist you in your decision, the table below shows how much money your partner receives depending on how much you decide transfer.

Amount you decide to transfer.	Amount your partner has to transfer.
0 SEK	0 SEK
10 SEK	30 SEK
20 SEK	60 SEK
30 SEK	90 SEK
40 SEK	120 SEK
50 SEK	150 SEK

Please indicate below how much you choose to give to your partner. (in multiples of 10-SEK):

___________________SEK

Instructions to Trustees, Sweden Experiment

In this section you have been randomly paired with another participant in this study (but nobody in this room). You will not find out who this person is, nor will he or she find out who you are (not now, nor after the experiment is over).

Your partner has been given 50 SEK and will decide what share of the money to transfer to you. Whatever money is transferred to you will be tripled, so for every 10 SEK the partner gives you, you get 30 SEK. You then decide what share of the tripled money to keep, and how much to return to you partner.

Please indicate in the table below how much money you give back at every possible sum of money which your partner might give to you. The decision you make at the sum of money which your partner actually gives you will then be used to calculate how much you earn.

Sum given to you by your partner.	Sum at your disposal after money has been tripled.	**Sum you decide to return to your partner.**
10 SEK	30 SEK	
20 SEK	60 SEK	
30 SEK	90 SEK	
40 SEK	120 SEK	
50 SEK	150 SEK	

USA Experiment Procedures

The institutional review boards at the University of California, Davis, and the University of California, San Diego approved the study and the recruitment of subjects.

Each subject in both phases of the experiment was given five separate opaque envelopes containing the instructions for each of five games and a set of coloured tokens. One of these games required the subject to be the investor and the other required the subject to be the trustee in the trust game. Subjects in California were instructed that they had been paired with a randomly assigned anonymous study participant. Subjects in Ohio were instructed that they had been randomly paired with an anonymous non-twin in California to play each game. Subjects in California were told they would be paid at the conclusion of the study (after phase two), while those in Ohio were told they would be paid at the end of the session. All subjects were told that one of their games would be chosen at random, and they would be paid based on the outcome of that game (12).

The token-to-cash equivalence for the payment was one token equals 0.65 dollars. When subjects were the investor, they were given 10 tokens and asked to place in an envelope the amount they wanted to send to the trustee. When they were the trustee, they were given the number of tokens sent to them by the investor, and then asked to place into an envelope the number they wanted to return to the investor. Some of the twins who played the investor received zero tokens because the trustee sent none – these individuals are not included in the analysis of trustworthiness. Upon completing the five experiments, subjects filled out a brief survey and were then paid by random assignment for one of the games they had played. A $5 participation fee was added to their total.

Instructions to Investors, USA Experiment

This game is played by pairs of individuals. Each pair is made up of a Player 1 and a Player 2. Each of you will play this game with a randomly assigned anonymous study participant in Davis, CA **specific to this game**. We will give 10 tokens to Player 1. Player 1 then has the opportunity to give a portion of his or her 10 tokens to Player 2. Player 1 could give some, all, or none of the 10 tokens. Whatever amount Player 1 decides to give to Player 2 will be tripled before it is passed on to Player 2. Player 2 then has the option of returning any portion of this tripled amount to Player 1.

Then, the game is over.

Player 1 receives whatever he or she kept from their original 10 tokens, plus anything returned to him or her by Player 2. Player 2 receives their original 10 tokens, plus whatever was given to him or her by Player 1 and then tripled minus whatever they returned to Player 1.

We will now run through 3 examples to show you how the game might be played.

1) Imagine that Player 1 gives 4 tokens to Player 2. We triple this amount, so Player 2 gets 12 tokens (3 times 4 tokens equals 12 tokens). At this point, Player 1 has 6 tokens and Player 2 has 12 tokens. Then Player 2 has to decide whether to give anything back to Player 1, and if so, how much. Suppose Player 2 decides to return 3 tokens to Player 1. At the end of the game Player 1 will have 9 tokens and Player 2 will have 9 tokens.

2) Imagine that Player 1 gives 3 tokens to Player 2. We triple this amount, so Player 2 gets 9 tokens (3 times 3 tokens equals 9 tokens). At this point, Player 1 has 7 tokens and Player 2 has 9 tokens. Then Player 2 has to decide whether to give anything back to Player 1, and if so, how much. Suppose Player 2 decides to return 0 tokens to Player 1. At the end of the game Player 1 will have 7 tokens and Player 2 will have 9 tokens.

3) Imagine that Player 1 gives 10 tokens to Player 2. We triple this amount, so Player 2 gets 30 tokens (3 times 10 tokens equals 30 tokens). At this point, Player 1 has 0 tokens and Player 2 has 30 tokens. Then Player 2 has to decide whether to give anything back to Player 1, and if so, how much. Suppose Player 2 decides to return 3 tokens to Player 1. At the end of the game Player 1 will have 3 and Player 2 will have 27 tokens.

Player 1: You are Player 1. Your 10 tokens are in the envelope for this game. Put the number of tokens you want to be tripled and passed on to Player 2 in the envelope for this game and seal it. Put the number you want to keep for yourself in the box you have been given. You can give Player 2 some, all, or none of the 10 tokens. Player 2 will receive this amount tripled by us. Remember the more you give to Player 2 the greater the amount of money at his or her disposal. While Player 2 is under no obligation to give anything back, we will pass onto you whatever he or she decides to return.

So,
Put the tokens you wish to **keep** in **box**.
Put the tokens you wish to **go to Player 2** in **this game's envelope**.

Instructions to Trustees, U.S. Experiment

This game is played by pairs of individuals. Each pair is made up of a Player 1 and a Player 2. Each of you will play this game with a randomly assigned anonymous study participant in Davis, CA **specific to this game**. We will give 10 tokens to Player 1. Player 1 then has the opportunity to give a portion of his or her 10 tokens to Player 2. Player 1 could give some, all, or none of the 10 tokens. Whatever amount Player 1 decides to give to Player 2 will be tripled before it is passed on to Player 2. Player 2 then has the option of returning any portion of this tripled amount to Player 1.

Then, the game is over.

Player 1 receives whatever he or she kept from their original 10 tokens, plus anything returned to him or her by Player 2. Player 2 receives their original 10 tokens, plus whatever was given to him or her by Player 1 and then tripled minus whatever they returned to Player 1.

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2) Imagine that Player 1 gives 3 tokens to Player 2. We triple this amount, so Player 2 gets 9 tokens (3 times 3 tokens equals 9 tokens). At this point, Player 1 has 7 tokens and Player 2 has 9 tokens. Then Player 2 has to decide whether to give anything back to Player 1, and if so, how much. Suppose Player 2 decides to return 0 tokens to Player 1. At the end of the game Player 1 will have 7 tokens and Player 2 will have 9 tokens.

3) Imagine that Player 1 gives 10 tokens to Player 2. We triple this amount, so Player 2 gets 30 tokens (3 times 10 tokens equals 30 tokens). At this point, Player 1 has 0 tokens and Player 2 has 30 tokens. Then Player 2 has to decide whether to give anything back to Player 1, and if so, how much. Suppose Player 2 decides to return 3 tokens to Player 1. At the end of the game Player 1 will have 3 and Player 2 will have 27 tokens.

Player 2: You are Player 2. The tripled number of tokens Player 1 decided to give to you is in the envelope for this game. You must decide the amount that you want returned to Player 1. Player 1 could have offered any amount from 0 to 10 tokens, which means you may receive any amount between 0 and 30 total possible tokens. Remember, you can choose to give something back or not. Do what you wish. Put the number of tokens you want to be passed on to Player 1 in the envelope for this game and seal it. Put the number you want to keep for yourself in the box you have been given.

So,
Put the tokens you wish to **keep** in **box**.
Put the tokens you wish to **go back to Player 1** in **this game's envelope**.

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