The robustness of the 'Raise-The-Stakes' strategy: confronting cheaters in noisy Prisoner's Dilemma Games.

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Abstract

Recent models of altruism point out the success of a strategy called 'Raise-The-Stakes' (RTS) in situations allowing variability in cooperation. In theory, RTS is difficult to exploit because it begins with a small investment in an iterated Prisoner's Dilemma Game. When its cooperation is reciprocated, RTS increases its generosity, thereby taking advantage of cooperative opportunities. Previous research has shown that human subjects indeed adopt RTS but start out moderately cooperative rather than with a minimal investment. This raises the question how robust RTS is against exploitation, certainly in a noisy situation. In a behavioral experiment we investigate whether human subjects vary their cooperation in interaction with reciprocators and cheaters in an iterated non-discrete version of a Prisoner's Dilemma Game. When confronted with a strategy that matches the investment of the subject on the previous round, we find that subjects are likely to increase cooperation. However, cooperation gradually breaks down in interaction with a strategy that undercuts the level of cooperation of the subjects, indicating the robustness of RTS. In line with RTS modeling studies, but in contrast with the cheater detection literature, we find that human subjects are less willing to increase cooperation when the perceived likelihood of mistakes increases.

Keywords: reciprocal altruism, evolution of cooperation, Prisoner's Dilemma, cheating, noise

1. Introduction

The evolutionary origin of cooperative behavior is an enduring puzzle. For several decades, various disciplines have tried to answer the question why an organism performs an act that is costly to itself and beneficial to another (e.g., Axelrod & Dion, 1988; Axelrod, 1984; Gintis, Bowles, Boyd & Fehr, 2003; Hamilton, 1964a, 1964b; Trivers, 1971). The 'Prisoner's Dilemma Game' (PDG) is the prevailing and orthodox framework for studying the evolution of cooperation, but it suffers from a procedural flaw when compared to the real-life situations it is designed to model. In a standard PDG players face a binary choice: whether to cooperate or to defect. Cooperation is however seldom an 'all-or-nothing' case (Killingback, Doebeli & Knowlton, 1999; Frean, 1996). Individuals can decide about the extent of their cooperation. Bats may vary cooperativeness in terms of the quantity of a meal shared (Wilkinson, 1984), impala may vary grooming time (Hart & Hart, 1992) and fish may vary cooperation by increasing or decreasing the inspection distance of a predator (Milinski, Lüthi, Eggler, & Parker, 1997). In line with Roberts and Renwick (2003), we explore in this study how human subjects gradually adapt the level of their cooperativeness throughout a series of interactions. We specifically investigate whether the strategy pursued by the opponent (subtle cheating vs. no-cheating) affects cooperation and how this is moderated by communication noise.

If interactions with variable investment levels are considered, a new kind of cheating is possible because some cooperators may be less generous than others (Sherratt & Roberts, 1998). Rather than a plain defection (in the dichotomous iterated PDG), individuals may invest a little less than their partners (in an iterated PDG that allows variable investment). In principle, this 'subtle cheating' could gradually erode cooperation. Cosmides and Tooby argued that for cheating not to have prevented cooperation from emerging, humans must have evolved domain-specific cognitive capacities that allow them to detect cheaters (Cosmides, 1989; Cosmides & Tooby, 1992). Natural selection should favor the ability to detect and discriminate against subtle cheaters (Trivers, 1971). There is even some evidence that cheaters may look different from cooperators (Yamagishi, Tanida, Mashima, Shimoma & Kanazawa, 2003). The capacity to distinguish defectors and cooperators allows humans to select partners that will reciprocate.

How do evolutionary strategies (and hence human cooperativeness) survive the potentially destabilising effects of this type of subtle exploitation? Roberts and Sherratt (1998) simulated interactions between a number of simple strategies (amongst which cheater strategies) and found that cooperation emerged. It did so through a strategy of 'Raise-The-Stakes' (RTS). RTS invests a minimal amount *(=a*) at first ('testing-the-water') and then increases the investment with a certain amount *(=b*), if and only if the partner matches or betters RTS' investment. RTS allows individuals to take advantage of cooperative opportunities while minimizing the risk of being exploited. Compare this strategy to the Tit-for-Tat (TFT) strategy that typically outperforms other strategies in the standard dichotomous PDG (Axelrod, 1984). TFT is less cautious on its initial move by starting with a cooperative choice. A nicely starting strategy, such as TFT, makes a giant 'leap of faith' on the first move and is vulnerable to exploitation by cheaters in a PDG with variable investment.

Roberts and Renwick (2003) tested whether the RTS strategy is adopted by human subjects in an iterated PDG with variable investment. The experiment supported Roberts and Sherratt's prediction (1998) that investment in cooperation increases over the course of an interaction. Subjects increased donations over successive rounds when the partner reciprocated the investment. On the first move, however, subjects donated a considerably greater amount than the minimal amount required to 'test the water'. This aspect of human behavior differed from the simulations but has an interesting implication. According to Robert and Sherratt's (1998) simulations, RTS' major advantage over TFT was its low initial cooperativeness, which immunizes the RTS strategy against exploitation. Therefore, an important question is whether the 'faithful' RTS strategy adopted by human subjects is robust against subtle cheating. The question what would happen when they are confronted with a cheater is legitimate, since natural populations are likely to contain a number of individuals that do not cooperate (Doebeli, Hauert & Killingback, 2004; Sherratt & Roberts, 2001). Starting at an intermediate level makes the 'faithful' RTS-like strategy vulnerable to exploitation. There has been no direct experimental test of whether the faithful RTS-like strategy adopted by the subjects (Roberts & Renwick, 2003) is robust against 'subtle cheating'.

Humans following a 'faithful' RTS strategy have three options when subtly cheated on. They can either ignore the cheating and maintain their cooperation level without raising the stakes; they can harshly punish by investing nothing on the subsequent round; or they can switch to TFT and match the partner's moves. Maintaining cooperation levels intermediate leads to a large relative fitness disadvantage because of an infinitely enduring exploitation by the subtle cheater. Turning to non-cooperation in reaction to a subtle defection has relatively high opportunity costs. Theory predicts that a partner's low investment is punished by matching the partner's choice (Killingback & Doebeli, 2002; Roberts & Sherratt, 1998; Sherratt & Roberts, 2002). Playing TFT signals that the cheating is noted, but that the opponent gets another chance and at the same time, opportunity costs for the actor are reduced to a minimum. We therefore expect human subjects to pursue a TFT-like strategy whenever confronted with a cheater, but an RTS-strategy whenever confronted with a reciprocator.

The robustness of RTS is not only determined by the strategy pursued by the opponent, but also by situational and contextual variables. Errors are likely to occur in reality and a single mistake can be calamitous for reciprocal altruism (e.g. Van Lange, Ouwerkerk & Tazelaar, 2002). The escalation of retaliation among Tit-For-Tat players after an occasional mistake gradually breaks down cooperation. A good way to cope with noise is allowing some percentage of the other player's defections to go unpunished (Nowak & Sigmund, 1992, 1993; Wu & Axelrod, 1995). Generosity might prevent a single error from eliciting a sequence of defections. Barrett (1999) and Cosmides and Tooby (2004) predict that people would be tolerant towards an nonintentional act of defection and make a distinction between an inadvertent mistake and intentional cheating. The interaction with a cheater strategy in a situation in which the perceived likelihood of mistakes is higher, could therefore result in higher levels of cooperation, compared to a game in which noise is absent. Evolutionary simulations (Sherratt & Roberts, 1999) however, have demonstrated that RTS-like strategies tend to become less generous as the probability of mistakes increases. To disentangle the two different hypotheses we explore the effect of noise on RTS strategies adopted by human subjects. Based on modeling studies (Sherratt & Roberts, 1999) we could predict that subjects would be less willing to raise stakes in noisy situations (both against subtle cheaters and non-cheaters). Based on the cheater detection literature, we could expect human subjects to display more generosity towards subtle cheaters as the perceived likelihood of inadvertent mistakes rises.

2. Material & Methods

2.1 Participants

Students (N=57) from the University of Leuven were recruited via the internet and participated in an iterated Prisoner's Dilemma game with variable investment (adopted from Roberts & Renwick, 2003 and Van Lange et al., 2002). Five to eight subjects attended each research session. The subjects were seated in one of 8 partially enclosed cubicles, which prevented them from communicating with each other. They participated in return for a participation fee that varied with their payoff in the experimental game (between €6 and €8.5).

2.2 Procedure

The instructions for the iterated Prisoner's Dilemma Game that allows for variable investment were given in the cubicle by a computer program written in Macromedia Authorware®. The task was conducted on PC. In each round of the game, subjects were allocated €10, which they could either keep to themselves or donate to the other player in units of €1 (ranging from 0 to 10 coins). Each €1 kept was added to the subject's account. Each €1 donated was doubled by the experimenter and added to the partner's account. The possible outcomes of the game were presented in an 11 by

11 matrix that could be consulted throughout the experimental task. Subjects were informed about the partner's decisions prior to making a subsequent choice. Subjects knew that the total amount of coins gathered throughout the PDG was used to calculate the participation fee. This made sure that decisions made in the PDG were involving. After explaining the game, the subjects acquainted with the choice procedure by 5 iterations of the task. These 5 test iterations made it clear to subjects that choices were made simultaneously. The subject was informed that her PC would be connected with another PC on a random basis and that choices were made anonymously. The subjects were unaware of the number of iterations of the game would be played.

2.3 Dependent Variable

In order to investigate the prediction of Roberts and Sherratt (1998) that investment in cooperation increases over the course of an interaction, a 'Raising-The-Stakes' coefficient was computed for each subject, by correlating round number with the number of coins the subject gave to the co-player. When subjects did not vary cooperation (*n*=10) and thus a correlation coefficient could not be computed, an RTS-coefficient = 0 was assigned. Since the sampling distribution of Pearson's r is not normally distributed, a Fisher z' transformation was employed to convert RTS coefficients to the normally distributed variable z'.

2.4 Conditions

2.4.1 Noise

In the noise condition, the computer 'checked' whether the network connection between the cubicles was stable: the subjects were informed by a pop-up window before the start of the iterated PDG, that choices would not always be correctly sent to the other cubicle ("due to a problem with the computer server"). The computers used were outdated and made this warning believable. The computer automatically checked the "server reliability" and informed the subjects before the interaction in the PDG that mistakes could occur. The interaction between the two players was briefly interrupted once after round 6 by another pop-up window. Interaction in the

PDG continued as soon as the subject clicked a button on the pop-up window. None of the player's choices were actually changed. In the 'no noise' condition, the interaction was never interrupted and the interaction in the PDG was not preceded by a 'warning about mistakes'.

2.4.2 Strategy

The subjects played, unbeknownst to them, against a pre-programmed computer strategy. This procedure allows us to record the variability in cooperation with a minimal amount of interference. Consistent with the conceptual definition of 'Tit-For-Tat' (TFT), TFT was programmed to begin by giving 6 coins to the subject, a nice and cooperative choice (Van Lange et al., 2002). In subsequent rounds, TFT was programmed to give exactly the same number of coins that the subject had given in the previous interaction round. The 'Tit-For-Tat-Minus-1' (TFT-1) strategy started by giving 6 coins on the first round and was programmed to subtract 1 coin from the subject's previous choice in the subsequent round.

2.5 Design

A within subjects design (each individual is subjected to each condition in a random order) was employed with Strategy and Noise as two independent within subject variables. At the end of the first condition, a filler task was given to the subjects and as soon as all subjects had finished the first interaction phase, they changed places and interacted in a second PDG with a different opponent. This procedure was repeated until the subjects had finished all four conditions.

3. Results

A 2 (strategy) by 2 (noise) within subjects analysis of variance, revealed a main effect for strategy, $F(1,168)=180.79$, $p<.01$. The positive correlation (M=0.57, Fisher transformed Pearson's correlation coefficient) between round number and level of cooperation among subjects interacting with the TFT strategy, indicates that subjects increased cooperation against a strategy that matched the player's investment. The interaction with a TFT-1 strategy yielded negative correlations (M=-0.71) between round number and level of cooperation, which indicates that subjects decreased cooperation over the course of an interaction with a strategy that undercuts the player's level of investment. The analysis also revealed a significant main effect of noise, *F*(1,168)=4.78, *p*<.05. When in a noisy situation subjects were less likely to raise stakes (M=-0.17) than when noise was absent (M=0.03). Subjects became less generous as the perceived probability of mistakes increased. The strategy by noise interaction did not yield a significant effect, *F*(1,168)=0.16, ns. Figure 1 shows the median cooperation level across the ten trials for the four conditions. Figure 2 shows the average correlations between round number and cooperation in the four conditions.

Insert Figure 1 about here

Insert Figure 2 about here

The analysis yielded an R-square of 0.61. The RTS coefficient was positive in both TFT conditions, irrespective of noise, indicating that subjects raised their level of cooperation throughout the interaction, whenever the partner matched their choices. In the noise condition (M=0.45), Fisher transformed RTS coefficients differed significantly from zero, *t*(56)=4.15, *p*<.01, 95% confidence interval: [0.23;0.67]. In the no noise condition (M=0.70), Fisher transformed RTS coefficients differed significantly from zero, *t*(56)=6.15, *p*<.01, 95% confidence interval: [0.47;0.93]. The RTS coefficient was negative in both TFT-1 conditions, irrespective of noise, indicating a decrease in cooperation over the course of the interaction when the partner undercuts the investment. In the noise condition (M=-0.81), Fisher transformed RTS coefficients differed significantly from zero, *t*(56)=-10.45, *p*<.01, 95% confidence interval: [-0.96; -0.65]. In the no noise condition (M=-0.63), Fisher transformed RTS coefficients differed significantly from zero, *t*(56)=-6.59, *p*<.01, 95% confidence interval: [-0.82; -0.47].

4. Discussion

In line with Roberts and Renwick's findings (2003), we found that cooperation increased throughout the interaction when investments of the subject were matched. Subjects raised stakes when they played against a pre-programmed computer strategy that gave exactly the same number of coins that the subject gave in the previous interaction round (i.e. Tit-for-Tat).

While previous research has shown that RTS is capable of taking advantage of cooperative opportunities, RTS' reaction on defectors is fairly understudied. This question is relevant because humans seem to adopt a 'faithful' RTS strategy: They start at an intermediate level which makes them vulnerable to exploitation. Populations are likely to contain a class of individuals that temporarily or permanently lack the time, energy, resources, ability, or willingness to cooperate (Sherratt & Roberts, 2001). Theory predicts that low investments of the partner are punished by matching the partner's level of cooperation (Sherratt & Roberts, 2002). The adaptation of RTS in a 'Tit-for-Tat' like strategy when human subjects interact with a 'subtle cheater' has, to our knowledge, not been researched yet. We found that cooperation decreased gradually throughout the interaction whenever the partner undercuts the cooperation of the subject. Rather than investing zero or maintaining an intermediate level of cooperation when confronted with a cheater, subjects adjusted their level of cooperation gradually downwards. This shift in strategy suggests that subjects discriminate cheaters and reciprocators, as has been put forward by Cosmides and Tooby (1992) and Trivers (1971).

In our experiment we simulated network problems with the computers on which the experimental task was completed. Modeling studies (Sherratt & Roberts, 1999) suggest that individuals become less generous as the probability of mistakes increases. Cheater detection theory, in contrast, suggests that noise would reduce the negative effects of subtle cheating strategies. In this way, humans would suffer less opportunity costs. Our data are in line with the first prediction. As subjects perceived a greater likelihood of mistakes, they were less willing to raise stakes against a reciprocator and less willing to give a cheater a new chance. In line with Sherratt & Roberts (1999), we interpret the non-cooperative behavior in noisy situations as subjects being more cautious when the perceived probability of errors rises. It seems as if the potential exploitation costs outweigh the opportunity costs in noisy situations.

In contrast with Roberts and Sherratt's initial simulations (1998) but consistent with Robert and Renwick's (2003), the initial move in the PDG is substantially higher than the minimal amount needed to 'test-the-water'. RTS-like strategies forego and delay potential gains by only investing a small amount on the first move, whereas TFT-like strategies are vulnerable to exploitation by starting out with a cooperative move. The potential cost of an initial cooperative move is underestimated in a standard PDG but could be quite substantial is a non-discrete PDG. A strategy cancelling out the opportunity cost carried by RTS strategies and minimizing the risk of exploitation carried by TFT strategies, should start out with a moderately cooperative move. Initial moves of human subjects could be the result of the combination of concerns about losing gains (i.e. opportunity costs) and exploitation and this could explain the moderately high levels of cooperation on the first round. A strategy that is informed about probabilities of meeting a cheater versus a reciprocator and adapt its initial move to these probabilities might be more successful than low starting RTS or high starting TFT strategies.

We extend previous findings by examining 'Raise-the-Stakes' in a situation where subjects make simultaneous offers, as opposed to a game where offers are made sequentially (e.g. Roberts & Renwick, 2003). It has been shown that outcomes for the alternating PDG can be quite different from the simultaneous case (e.g. Frean, 1994; Nowak & Sigmund, 1994; Wedekind & Milinski, 1996). The replication of the findings of Roberts & Renwick (2003) suggests the viability of RTS in both the alternating and simultaneous situations. As noted by Wedekind & Milinski (1996), both the simultaneous and the alternating cases could have been part of human ecology. In contrast with Roberts & Renwick (2003) we did not find ceiling effects in cooperation towards the end of the interaction. This could be due to the fact that the orientation to long term consequences by successive turn taking reduces competitiveness. In a sequential game the participant might think ahead and be planful regarding the maximization of long-term outcomes (Insko et al., 1998). Hence, the sequential game could increase the level of cooperation at a faster rate, because of the anticipation of the partner's subsequent choice.

We found that human subjects add a small amount (=*b*) to their level of cooperation when investments were reciprocated and that subjects punish lower investments by matching the partner's move. Theory predicts that if the partner's cooperative investment exceeds RTS' level of cooperation, RTS should respond by adding an even bigger amount (=*2b*) to its own previous investment (Sherratt & Roberts, 2002). Future research could investigate whether human subjects double their stakes when they interact with RTS, creating an even more rapid upward spiral of increasing cooperation. Some cooperators however may be less generous than others (Sherratt & Roberts, 1998) and subjects might differ in their willingness to raise stakes: personality variables, such as Social Value Orientation (e.g. Van Lange, 1999), could explain inter-individual differences in the *b*-parameter that characterizes RTS. Additionally, future research could investigate whether other situational factors might affect the adoption of RTS by humans. Subjects knowing that their choices in a PDG will be made public at the end of the game might act more generously than subjects whose choices are made anonymously. Subjects may perceive that being cooperative would enhance one's reputation (e.g. Barclay, 2004; Nowak & Sigmund, 1998). The possibility of indirect reciprocity might boost RTS. Finally, future research could explore why situational noise does not buffer the negative effects as cheater detection theory suggests. Possibly, noise buffers a decrease in cooperation only when it is even more subtle (cheating occasionally rather than defecting all the time)?

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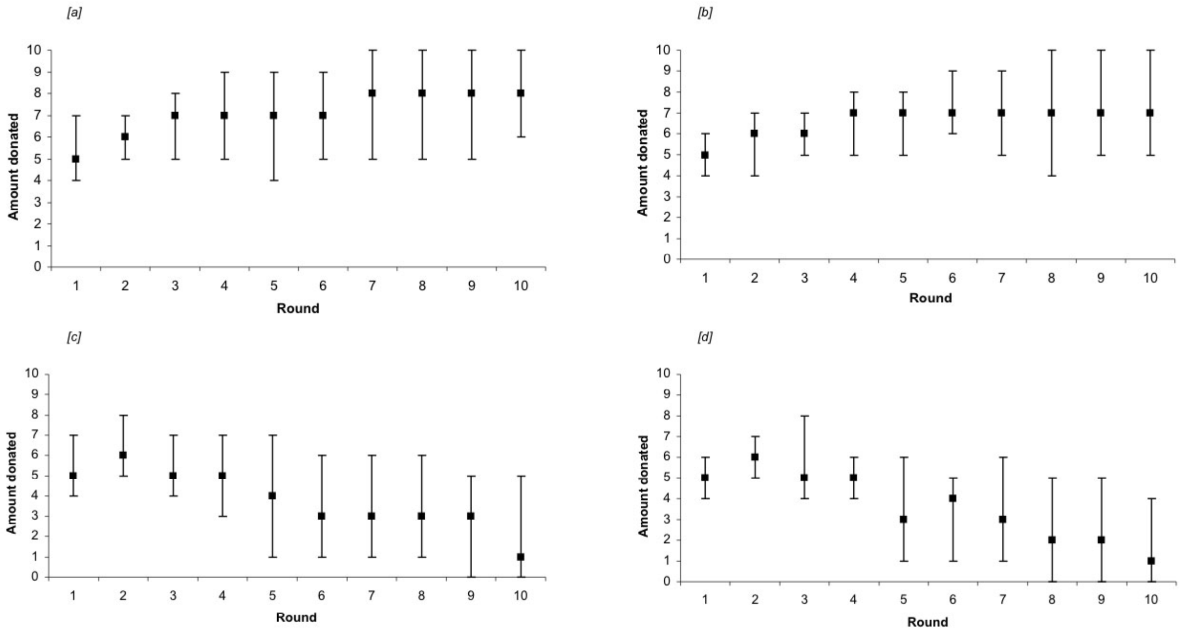

Figure 1. The amount given in each round in [a] the TFT & No Noise condition; [b] the TFT & Noise condition; [c] the TFT-1 & No Noise condition; [d] the TFT-1 & Noise condition. Data are plotted as medians across 57 subjects with 25% and 75% quartiles.

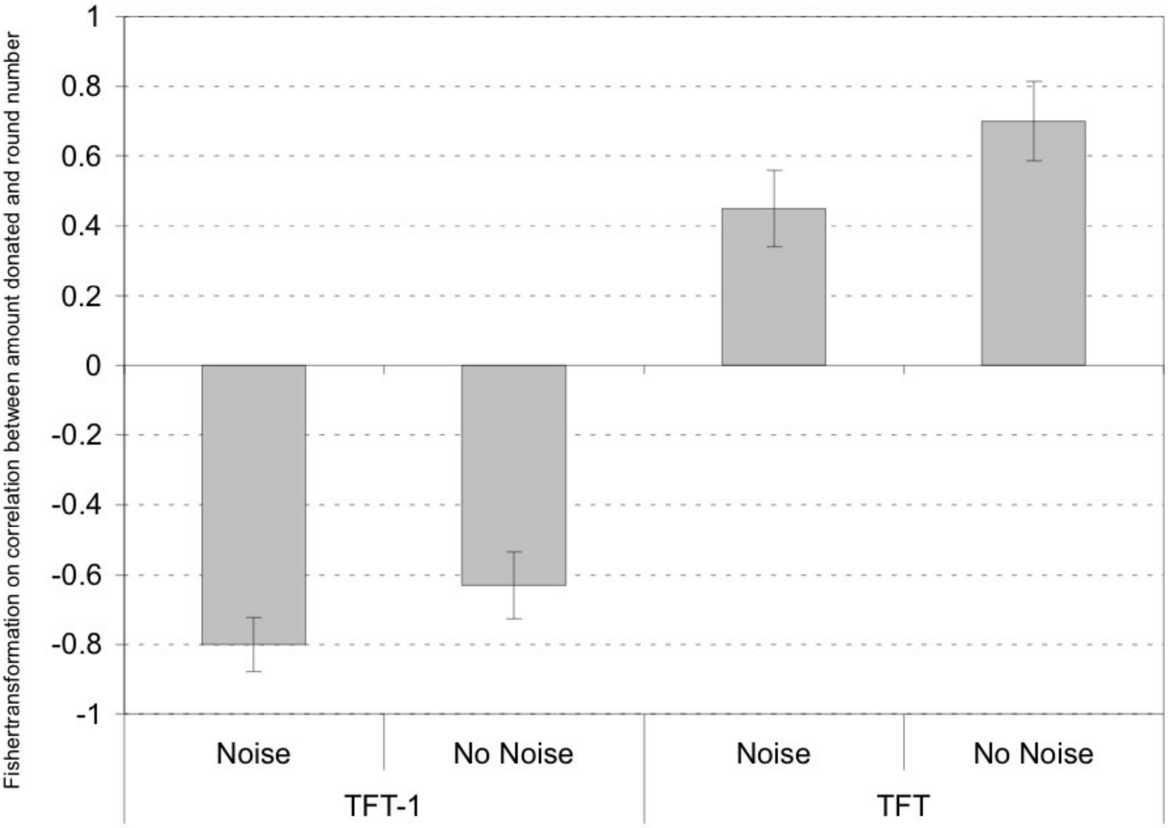

Figure 2. 'Raising-the-Stakes'-coefficients for all conditions. Standard errors and mean Fisher transformed correlations coefficients between round number and amount donated are plotted.