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Wholly Altruistic Systems Derived from Quasi-Altruistic Agents: An Evolutionary Study

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With the publication on John von Neumann's and Oskar Morgenstern's book *Theory of Games and Economic behavior* (1944) and John F. Nash's *Equilibrium Points in n-person Games* (1950), economics was given powerful modeling tools to study behavioral interactions. These tools however, are still with limitations, relying heavily upon assumptions that *Homo economicus* is perfectly rational and can compute complex decisions costlessly and efficiently. This assumption was loosened by the argument of bounded rationality, which argues that humans are not capable of making efficient decisions because they can not acquire complete information and do not possess the skills to calculate wholly efficient outcomes. With the development of bounded rationality and the publication of Maynard Smith's (1982) *Evolution and the Theory of Games,* evolutionary models finally gave economist accurate tools to model strategic human interaction. The strategic play between agents has existed as long as agents have been placed in environments where scarcity is an issue, and according to evolutionary theory strategies that perform poorly will get selected out of the population. However, most humans in any given population find themselves playing quasi-altruistic strategies. Altruism in an evolutionary sense is any strategy that benefits ones opponent at a cost to oneself, Bergstrom and Stark (1993) or any behavior that reduces the actor's fitness while increasing the fitness of another. Bergstrom and Stark (1993) have demonstrated that even in some highly specified populations pure altruistic strategies can survive. But most humans do not live in these highly specified environments and still show some signs of altruistic behavior. If evolutionary dynamics propagates stronger strategies, humans should show no signs of altruism, because altruistic preferences are generally weaker than egotistical ones.

Much work has been done on the study of altruistic strategies. As previously mentioned Bergstrom and Stark *How Altruism Can Prevail in an Evolutionary Environment* (1993) asserts that evolutionary altruism can exist in siblings, and other specific environments. Bergstrom has written many other papers dealing with siblings and altruism. Simon (1993) asserts that altruism exists as a form of coping with the limitations of human rationality. Paul Samuelson (1993) shows that altruism is a problem between group and individual selection. *Altruists, Egotists, and Hooligans in a Local Interaction Model* by Eshel, Samuelson, and Shaked (1998) makes a very good case for altruists in local models. For the theoretical framework Maynard Smith's (1982) *Evolution and the Theory of Games* is indispensable for the argument. Nelson and Winter (2002) make a good case for evolutionary economics and present a fine survey of the theoretical literature on the subject. These are all valid arguments, but concentrate on single shot games, which do not accurately model continual interaction. This paper will evaluate human interaction based on sustained encounters between agents. The reasoning behind this assumption is humans are a sociable species who readily form and maintain relationships. It is far more accurate to model human interaction based on regular encounters and sustained interaction, rather than random pairings and single shot games. Altruistic systems can evolve and remain evolutionary stable through agents who play quasi-evolutionary strategies.

I. GAME THEORY

Games are highly specialized environments where the payoff to both players is directly determined by the actions the other player takes. Each player's predetermined action is called a strategy. Strategies vary depending on the game but always include a choice between two or more options. A simple game would go like this:

Bob and Sally go to a restaurant and both prefer chicken wings to any other food. The restaurant produces orders of chicken wings in two serving batches, however if only one person orders wings they get both servings because the restaurant has no capacity to keep the excess wings warm. If Bob orders wings and sally doesn't Bob gets six points because he receives twice as many wings for the same price, and Sally gets two points because she gets a regular size serving of a lesser preferred food. If Sally orders wings, and Bob doesn't, Sally gets six points because she gets both orders for the same price, and Bob gets two points because he gets a regular size of a lesser preferred food. If both people order wings they both get three points because they share the wings. If no one orders wings Bob and Sally both get two points because they are ordering food of a lesser preference.

Figure 1

	Order Wings	Do Not Order Wings
Order Wings	**3** / **3**	**2** / **6**
Do Not Order Wings	**2** / **6**	**2** / **2**

Figure 1 is what is referred to as a normal form game, which shows the payoff for each player depending on how the game is played. The equilibrium of this game is not hard to find, both players will order wings and both receive three points. Equilibrium outcomes in games are called Nash equilibria, names after John Forbes Nash jr. who originally developed the solution to such problems. They exist when both players play a best response function against each other. They best response in the game above is to order wings, because no matter what the other player does, ordering wings will generate the highest payoff. If both players play their best response, order wings, both could do no better with any other strategy and the game would be in equilibrium, where both players order wings. Not all games have such obvious equilibria. Another Game:

You and your opponent both agree to go to a party. You chose to bring or not to bring a forty and your opponent will choose to bring or not bring a bottle of wine. Both of you agree to share whatever you bring. If you decide to bring a forty and your opponent decides to bring a bottle of wine, then you both share and each receive five points. If you bring a forty and your opponent does not bring wine, your opponent gets to share your forty, but does not have to pay for anything, thus receiving eight points while you receive one point. If you do not bring a forty but your opponent brings wine then you get to share the wine at no cost and receive eight points while your opponent receives one. If no one brings anything to the party at all, both of you drink Natural Lite out of a keg and both receive three points each.

Figure 2

	Bring (Collude)	Do Not Bring (Defect)
Bring (Collude)	**5** **5**	**8** **1**
Do Not Bring (Defect)	**1** **8**	**3** **3**

This type of payoff (Figure 2) is actually called a prisoner's dilemma (P.D) game, which was based on the original game where two prisoners decide to either confess or not confess. The Nash equilibrium is where both players do not bring anything, or defect, because defection is the best response to any action the other player takes. If the other player colludes defection will bring eight points, if the other player defects, defection will bring three points. Collude, collude cannot be a Nash equilibrium because each player could do better by defecting. It is obvious that if both players collude they will earn more points than if they both defect, and that is the reason this is called a dilemma.

Now consider playing this game not once, but a number of times over and over again, adding up the cumulative score over the entire game. This is called a repeated game, because it is repeated. The strategy for repeated games differ from single shot games, especially in P.D games, because both players can do a lot better by sustaining a collude, collude relationship over a time. Consider a 10 round game, if both players defect all the way through they both earn 30 points. If both players collude all the way through they both earn 50 points. It is worth taking the chance on the first round to collude and receive a much higher payoff. The best known strategy that employs this method is called a tit-for-tat strategy, where the player always colludes on the first turn, then does whatever the other player did on the previous turn. If the game starts where both players collude and collusion continues, then there is pressure to defect right before the last turn to capture the higher payoff. This is in fact the best strategy but is hard to accomplish because both players are assumed to know this. Consider a 100 turn repeated P.D game. Both players start by colluding and each know that the other will defect on round 99, so each player defects before that round. The specific point where each player defects is known as a defection point. Defection points vary widely but all try to do the same thing, capture the excess payoff, while maximizing the current collude, collude situation.

II. EVOLUTIONARY GAME THEORY

Game theory is a very useful tool in modeling strategic outcomes, but there are downfalls with using it to model human interaction. Game theoretic models assume that each player is rational and can solve effectively the sometimes-complex decisions that the equilibrium outcome of games demand. Also there may exist several Nash equilibria in any given game, game theory does not tell at which ones humans will arrive; it just tells us where they are.

Figure 3: Samuelson (2002)

	In	Out
In	**2** **2**	**0** **0**
Out	**0** **0**	**0** **0**

The Joint Venture game gives a very good example of the difference between evolutionary game theory and game theory. Consider a game where two people are given the opportunity to form a joint venture and adhere to the payoff scheme of Figure 3. If both players go IN, they each receive a profit of two, if not the both recipe 0. Both IN, IN and OUT, OUT are Nash equilibria but at which point will humans arrive. In Evolutionary theory there is only one evolutionary stable outcome, IN, IN.

Evolutionary game theory was actually developed by biologist to study the evolution of animals in the wild. Economist started applying it because it allows natural selection of strategies to determine the outcome of games and populations. Evolutionary game theory assumes that there exists a population consisting of agents each "hard-wired" with a specific phenotype, or strategy. A hard-wired strategy is the strategy the agent plays no matter what; it is embedded in his/her genes, and governs how they interact with the rest of the population. Then agents are paired at random to play games; those who do better are said to have a "fitter" strategy. The fitness of a strategy depends on how well it does relative to the rest of the population. Evolutionary outcomes are the result of dynamic selection; agents who are "hard-wired" with weaker strategies die out, while agents with fitter strategies propagate faster and dominate the population. In economic games this can be easily seen where players using fitter strategies do better, and are imitated by the player's acquaintances or other observers. Evolutionary game theory is basically the natural selection of strategies; stronger strategies propagate themselves faster and come to dominate the population, while weaker strategies die out. During this process of random gaming, "mutations" among the agent's phenotypes in the population might occur by some random chance. Mutations might do better against the prevailing strategy within the population, and be able to successfully invade and dominate the population. If the strategy within the population cannot be successfully invaded by a mutant it is said to be an evolutionary-stable strategy (ESS). Conversely, if the population can be successfully invaded it is cannot be evolutionary stable.

Consider a population where each agent is hard-wired to play the OUT strategy, or the IN strategy in the joint venture game (Figure 3). When two OUT players are paired by chance the outcome is 0, 0 because each agent is born to play OUT. When Two IN players are paired by chance they both receive 2. IN players do better and during the next round of play there will be more IN players, due to higher rates of propagation, or imitation. Through the rounds IN players will come to dominate the population and OUT players will die out. The strategy of IN is an ESS because no mutant OUT player could successfully invade the population.

III. ALTRUISM

First we must revisit the definition of what altruism is, and how it affects human behavior. Altruism in an evolutionary sense is any strategy that benefits ones opponent at a cost to oneself, Bergstrom and Stark (1993) or any behavior that reduces the actor's fitness while increasing the fitness of another. Simon (1993, pg. 156). Altruistic strategies are by definition weaker, so they should have been weeded out of the population a long time ago, but even today humans display acts that lower their fitness while increasing the fitness of others.

To model the existence of altruism this paper will use a repeated P.D. game of an undisclosed horizon for several reasons. The strategy of collusion is a strictly dominated strategy, and lowers the agent's fitness while increasing the opponents. Also in groups, collusion rises the fitness of the group at a cost to the individual. Although wholly altruistic agents will be selected out, wholly altruistic outcomes can exist through quasi-altruistic agents. I deem tit-for-tat agents rational altruists, because they incur a cost due to risk on the first round of play, and then adjust accordingly. They are rational in the sense that they only get fooled once, but they are altruistic because of their tendency toward collusion, and the risk they incur on the first round of play. Timid-altruistic agents, agents who defect on the first round, then collude on the second round if matched against a tit-for-tatter, or defect on the second round if paired with a defector, could also exist if their where a high enough amount of tit-for-tat agents, or pure altruists. For the purpose of this paper the two phenotypes of the population will include egotists (defector agents), or rational altruists (tit-for-tat agents).

For the existence of an evolutionary stable altruistic system, three assumptions must be made.

1. The repeated game must be of an undisclosed horizon
2. There must be an appropriate discount rate
3. The initial distribution of agents must be sufficient to support rational altruists

The repeated game must be of an undisclosed amount of rounds; the players must not know when the game will end. This is a valid assumption because in life humans do not know when repeated games will end among close associates, relatives and friends. Unless the agent moves, or dies the game will go on with a relatively small chance of coming to an end. This assumption is made to counter defection points that occur near the end of a repeated game. If agents know when the game or relationship will end, they will defect before it is over.

The discount rate also deals with the longevity of the game. If the payoff in the future is discounted so it is worth less than the payoff of defecting in the next round, then the player will defect.

$$\text{IF:} \quad \sum^{t-n} E(\prod c) \,/\, (1-r)^{t-n} < E(\prod d) \quad \text{Then the player will defect.}$$

Where, t = termination round, n = next round, $\prod c$ = payoff of collusion, $\prod d$ = payoff of defection

This is also a valid assumption, backed by assumption one. If the player has no real idea of how many rounds are left in the game the payoff in the future cannot be appropriately discounted, and making a mistake of discounting to much may cause the player to defect too early, costing the player many rounds of higher payoffs. However, the higher the discount rate goes the lower the cost of guessing goes, so with a very high discount rate defection points might exist.

The initial distribution of agents in a population is the most important assumption and most difficult to validate. With too many egotist in the initial population all rational altruist will be selected out, because the probability that he/she would be paired with another rational altruist, and score higher than an egotist would be too small to effectively dominate the population. However, the longer the game runs, the excess payoff that the egoists receive from defecting on the first round becomes increasingly small relative to the amount of payoff colluding agents receive. Consider the payoff from the repeated P.D game (Figure 2).

Figure 2

	Bring (Collude)	Do Not Bring (Defect)
Bring (Collude)	**5** / **5**	**1** / **8**
Do Not Bring (Defect)	**8** / **1**	**3** / **3**

If the agents in this population are randomly paired to play a 10 round repeated P.D game then the normal form game actually looks like this.

Figure 4

	Collude (Rational Altruist)	Defect (Egotist)
Collude (Rational Altruist)	**50** / **50**	**28** / **35**
Defect (Egotist)	**35** / **28**	**30** / **30**

If a rational altruist meets a rational altruist they both collude continually for ten rounds and earn 50 points each. If two egotists meet they both earn 30 points each. If an egotist meets a rational altruist the egotist get 35 points while the rational altruist gets 28 points. If there are significantly more egotists in the initial population then the population will evolve entirely into egotists. If the population starts with a high number of rational altruists then the population will evolve into entirely rational altruists who continually collude. Say X, $0< X < 1$, is the population proportion of rational altruists, and therefore, (1-X) is the population proportion of egotists.

The expected payoff of a rational altruist is

$$50X + 28(1\text{-}X) = 22X + 28$$

$$E(\Pi \text{ r.a}) = 22X+28$$

The expected payoff of an egotist is:

$$35X + 30(1-X) = 5X + 30$$
$$E(\Pi \text{ e.}) = 5X + 30$$

A rational altruist is fitter than and egotist if:

$$22X + 28 > 5X + 30$$
$$17X > 2$$
$$X > .1176$$

A rational altruist is fitter that an egotist if more than 11% of the population is already a rational altruist. If there is an initial assignment of anything greater than 11%, rational altruists will evolve into a stable population, or an ESS. The initial population requirement decreases with an increase in rounds played per repeated game. If the initial assignment is exactly 11% rational altruists, and 89% egotists then the population will evolve when a random mutation occurs and tips the scale. With only quasi-altruistic players, a stable system of altruism can evolve.

In an evolved altruistic system of players composed of rational altruists, invasions of egotistical mutants will fare poorly and fail to invade the population successfully. If a mutation of a purely altruistic player occurs, a player who colludes no matter what, then they receive the same payoff of the fitter strategy of the rational altruist. This is called a neutral stable strategy, because they receive the same payoff as the fitter strategy, but if by chance they played an egotist mutant they would fare absolutely horribly.

With these three assumptions and the proper assignment of initial players altruistic populations can form and remain, as an evolutionary stable system, propagated by quasi-altruistic agents in repeated games of undisclosed horizons.

IV. EMPIRICAL EVIDENCE

To try and prove that systems like this can in fact form in real life, by real human players, an experiment was conducted to gather data on repeated P.D. game play. The experiment was designed to try and simulate each condition accurately. There were two groups of participants, economic majors (Group 1), and those who have never taken an economics class (Group 2). The economic majors were assumed to have prior knowledge and experience with repeated game play. This was suppose to simulate an already evolved player, someone who has studied repeated games should know about the tit-for-tat strategy, and have a basic understanding behind the theory. Non economic players were assumed to have no background with repeated games, and were assumed to be un-evolved players. The game was designed so that each player played a number of games, but never against the same opponent. Also to try and stop defection in later rounds of play, the rounds were alternated between 9, 10, and 11. By adding some uncertainty into the amount of rounds played I hoped that players would have a harder time judging when to defect therefore curbing the tendency to do so. The participants were handed directions (Appendix) and all questions were answered. Participants waited in a room next to the gaming area and were asked not to discuss strategy amongst each other. Each participant was assigned a number and when their number was called they were to play the game. When their number was called they came to the gaming area, were blindfolded and given little signs to signal "collude" or "defect". The experiment started on round one, to which both players would signal "collude" of "defect". After each round the players were relayed their score so they knew what had happened in that round. After the game was over they were given their game score against there opponent. The player's game scores were added to form a total score and were evaluated on how well they did against the group.

V. ANALYSIS

The experiments yielded very interesting results overall that coincided with my hypothesis, and gave light to very specific and fascinating anomalies in rounds of play. Group one participants, the economic majors, generally had a clear and defined strategy of play. Group two participants, the other majors, had a more random strategy set.

The participants in group one each played three games, of which only the first nine rounds were summed to form their score. There existed four clear egotists, those who always play defection strategies, the egotists were players 1, 4, 5, and 6. There were four mixed players, where sometimes they played defection strategies, and other times they colluded. These were players 7, 8, 9, and 10. There were five rational altruists, those who generally played cooperative strategies. These were players 2, 3, 11, 12, and 13. The highest scoring player was player 13, with a score of 139 points. This leads me to believe that in later games played more agents would imitate the strategy of player 13 which is that of a rational altruist. The averages score amount for the rational altruist was 111.8 points, while the egotist had an average of 105. This again supports that rational altruists play a fitter strategy that would be imitated, prorogated and become stable within the system.

There were interesting occurrences within the games of play, which should be pointed out. Several times a cooperative outcome came into existence not by normal tit-for-tat play of collusion of the first round but by missed and corrected for cooperation. Player 9 versus player 11, player 13 versus player 10, and player 11 versus player 1 all had sustained collusion resulting after a first round defection. This could be a way of insulating the risk associated with random pairings. By defecting on the first round one can guard him/herself from an egotist, but once the opponents strategy is identified a rational altruist, the player colludes on the second and third round to form and remain in collude/collude play.

Player 7 vs. player 6 yielded an interesting insight into purely altruist strategies. Player 7 colluded no matter what and was slaughtered. Player 7's second game resulted in stable collusion but by the third game the player switched to defection strategies. This shows that pure altruism dies relatively quickly as better strategies are hastily adopted. Defection points, marked by *, appeared among the rational altruist's, although the experiment was designed to avoid such play. There were several perfect games where a stable collusion outcome was defected upon on the last round of play, player 13, and game 1, 3, and player 3, game 2. By the third game nearly all of the rational altruists were playing defection strategies.

The players of mixed strategies showed a dynamic shift from their original strategy. Two players 9, 10 shifted from defection strategies to collusion tendency, player 8 went from collusion to defection strategies, and player seven was mentioned before. Players 9,and 10 seemed to learn that colluding could be beneficial and adjusted their strategies accordingly. Player 8, went from steady collusion to defection, which is counter-intuitive, since the expectation would be the other way around.

Overall Group 1 performed rationally with defined strategies and had outcomes along the lines that were theoretically predicted. The group showed that the initial assignment of agents in the system was enough to support a wholly altruistic system. Since the rational altruists scored on the average higher than the egotists, and the highest scoring player was a rational altruist, theoretically through evolutionary dynamics this group would evolve to a wholly altruistic system created by quasi-altruistic players. However, to conclude empirically that the group would in fact evolve that way would require resources beyond the scope of this paper. It is enough to see that the initial conditions for the theoretical evolution to altruistic systems have been met.

Group 2 displayed generally mixed and confused strategy sets. While there were six players that generally followed cooperative strategies, many cooperators defected on the second round of play then seemed to randomly collude at different intervals during the game. The egotists just played defection strategies. There was one player, player 5, who could be considered a pure altruist and took a considerable amount of loss by playing that strategy. Player 5, unlike player 7 in group one, did not change his strategy and took losses thorough the games of play.

The average egotist earned 148 points, while the average cooperator earned 125 points. Theoretically there are enough rational altruists to support continued cooperative play, but the bizarre and random defection points, and the random mid-game collusion did not allow those players to enter into sustained cooperation. Since the strategy sets were so random it makes sense defectors would have a higher average score since they could always take advantage of random collusion moves that the cooperators made.

The data generated by Group 2 lends less insight into the theoretical evolutionary outcome of the group because the strategy sets are much less defined. Since participants of group two had no formal education about the theory of games their strategies could be seen as less refined or evolved as the group one strategies. Looking at the data in this fashion we could conclude that if group two were left to evolve through evolutionary dynamics, they first would arrive at clearly defined strategy sets, rational altruists, or egotist would emerge, and then vie for population dominance. This makes theoretical sense but to empirically test the outcome would again require resources far beyond the scope of this paper. Group 2 lets us see that economics majors played clearer more refined strategies, supporting the assumption that they could be considered more refined players.

VI. CONCLUSION

It is theoretically possible if conditions are met that wholly altruistic system can evolve from quasi-altruistic players. The empirical data, while inconclusive that those systems do form, supports the notion that human players do play cooperative strategies, earn higher payoffs from those strategies, and supports the condition of sufficient initial assignment of rational altruistic agents. While the empirical data to prove the formation of those systems is beyond the reach of this paper, the observations of human interaction are not. Humans are social creatures, we form groups of people that we interact with in a kindly fashion. Altruistic behavior is not in any way unobservable in the real world. Humans constantly incur cost on themselves for the benefit of a group, or the chance to enter into a continuous beneficial relationship. Egotistical behavior is also highly observable in the real world, and the existence of that behavior has been well documented for centuries. Altruistic systems are theoretically possible, and do exist in the world.

So it is strange to say that *Homo economicus* is completely egotistical, and it seems completely reasonable to consider some human behavior as humane.

APPENDIX

Directions

1. You will each be assigned a number, please remember that number.
2. When your number is called please go to the Econ suite offices.
3. Once there, you will be blindfolded and asked to play a game against your opponent.
4. The Game: Forty's and Wine

You and your opponent both agree to go to a party. You chose to bring or not to bring a forty, and your opponent will chose to bring or not bring a bottle of wine. Both of you agree to share whatever you bring. If you decide to bring a forty and your opponent decides to bring a bottle of wine, then you both share and each receive five points. If you bring a forty and your opponent does not bring wine, your opponent gets to share your forty, but does not have to pay for anything, thus receiving eight points while you receive one point. If you do not bring a forty but your opponent brings wine then you get to share the wine at no cost and receive eight points while your opponent receives one. If no one brings anything to the party at all, both of you drink Natural Lite out of a keg and both receive three points each.

The Payoff Matrix looks like this:

	Bring	**Don't Bring**
Bring	5,5	1,8
Don't Bring	8,1	3,3

5. While blindfolded A round number will be called out, to which you will play the game by raising your right hand to signal bring (collude), or your left hand to signal not to bring (defect)
6. Your score for that round will be relayed to you, and the next round will start
7. The game will continue for several rounds
8. Your points for each round will be added up and you will receive a total score against that player.
9. After the game, go back to room 106, eat some food and await your next game.
10. Your points against each player will be added up to give you a total score.
11. Players with the highest total scores win.

PLEASE ASK ANY QUESTIONS IF ANYTHING IS UNCLEAR

Note: If you feel uncomfortable with the description of the game, switch forty to brownies, wine to cookies, and Natural Lite to cake.

Data

All data was collected during the experiment. Group one consists of the economic students, while group two consists of non-economic students. All data was collected at the same. An asterisk next to the score represents a defection point. Every attempt was made to keep the results unbiased and accurate. A Key for the layout is represented here:

		Player Number			Collude						
		Round Number									
Player Vs.	Game	1	2	3	4	5	6	7	8	9	10	Score
Player 2	1	C, 5	D,8	C,1								14
Player #	2											
Player #	3											
Player #	4											
										Total Score		14

The player's number is followed by what classification of player he/she is. Beneath the player's number is the round number 1 through 10. The chart is read from left to right, where each game has ten rounds. For example: this player played against player two in game one. One the first round this player colluded represented by C followed by the score earned 5. In the second round of the first game the player defected, represented by D, earning a score of 8. The third round of the game the player colluded but only earned a score of 1. The total game score is shown at the far right of the chart and the total players score is shown in the bottom right. After the first game is completed after 8, 9, or 10 rounds then the player will play game number two against the next player represented in the next column, again read form left to right.

Group 1

Player 1 Defect

Round Number

Player Vs.	Game	1	2	3	4	5	6	7	8	9	10	Score
Player 2	1	D,8	D,8	C,1	D,3	D,8	D,8	D,8	D,3	D,3		50
Player 12	2	D,8	D,3	C,1	D,8	D,3	D,3	D,3	D,3	D,3		35
Player 11	3	D,8	C,1	D,8	D,3	D,3	D,3	D,3	D,3	D,3		35
											Total Score	120

Player 2 Collude

Round Number

Player Vs.	Game	1	2	3	4	5	6	7	8	9	10	Score
Player 1	1	C,1	C,1	D,8	D,3	C,1	C,1	C,1	D,3	D,3		22
Player 3	2	C,5	C,5	C,5	C,5	C,5	C,5	C,5	C,5	C,5	D,8*	45
Player 13	3	C,5	C,5	C,5	C,5	C,5	C,5	C,1*	D,3	D,3		37
											Total Score	104

Player 3 Collude

Round Number

Player Vs.	Game	1	2	3	4	5	6	7	8	9	10	Score
Player 4	1	C,1	C,1	D,3	D,3	D,8	D,3	D,3	D,3	D,3	D,3	28
Player 2	2	C,5	C,5	C,5	C,5	C,5	C,5	C,5	C,5	C,5	D,8*	45
Player 9	3	C,5	C,5	C,5	C,5	C,5	C,5	C,1*	C,1	D,3	D,3	35
											Total Score	108

Player 4 Defect

Round Number

Player Vs.	Game	1	2	3	4	5	6	7	8	9	10	Score
Player 3	1	D,8	D,8	D,3	D,3	C,1	D,3	D,3	D,3	D,3	D,3	35
Player 7	2	C,1	D,3	D,3	D,3	D,3	D,3	D,3	D,3	D,3	D,3	25
Player 5	3	D,3	D,3	D,3	D,3	D,3	D,3	D,3	D,3	D,3		27
											Total Score	87

Player 5 Defect

Round Number

Player Vs.	Game	1	2	3	4	5	6	7	8	9	10	Score
Player 4	1	D,3	D,3	D,3	D,3	D,3	D,3	D,3	D,3	D,3		27
Player 6	2	D,3	D,3	D,3	D,8	D,3	D,3	D,3	D,3	D,3	D,3	32
Player 8	3	C,1	D,3	D,8	D,3	D,3	D,3	D,3	D,3	D,3	D,3	30
											Total Score	89

Player 6 Defect

Round Number

Player Vs.	Game	1	2	3	4	5	6	7	8	9	10	Score
Player 5	1	D,3	D,3	D,3	C,1	D,3	D,3	D,3	D,3	D,3	D,3	25
Player 7	2	D,8	D,8	D,8	D,8	D,8	D,8	D,8	D,8	D,8	D,8	72
Player 9	3	D,3,	D,3	D,3	D,3	D,3	D,3	D,3	D,3	D,3		27
											Total Score	124

Player 7 Collude/Defect

Round Number

Player Vs.	Game	1	2	3	4	5	6	7	8	9	10	Score
Player 6	1	C,1	C,1	C,1	C,1	C,1	C,1	C,1	C,1	C,1	C,1	9
Player 3	2	C,5	C,5	C,5	C,5	C,5	C,5	C,5	C,5	C,5	C,1*	45
Player 4	3	D,8	D,3	D,3	D,3	D,3	D,3	D,3	D,3	D,3		32
											Total Score	86

Player 8 Collude/Defect

Player Vs.	Game	1	2	3	4	5	6	7	8	9	10	Score
Player 11	1	C,5	C,5	C,5	C,5	C,5	C,5	C,5	C,5	C,5	C,5	45
Player 10	2	D,3	D,3	D,3	D,8	D,3	D,3	D,3	D,3	D,3	D,3	32
Player 5	3	D,8	D,3	C,1	D,3	D,3	D,3	D,3	D,3	D,3	D,3	30
											Total Score	107

Player 9 Defect to Collude

Player Vs.	Game	1	2	3	4	5	6	7	8	9	10	Score
Player 6	1	D,3	D,3	D,3	D,3	D,3	D,3	D,3	D,3	D,3	D,3	27
Player 11	2	D,8	C,1	C,5	C,5	C,5	C,5	C,5	C,5	C,5	D,8*	44
Player 3	3	C,5	C,5	C,5	C,5	C,5	C,5	D,8*	D,3	D,3	D,3	44
											Total Score	115

Player 10 Defect to Collude

Player Vs.	Game	1	2	3	4	5	6	7	8	9	10	Score
Player 8	1	D,3	D,3	D,3	C,1	D,3	D,3	D,3	D,3	D,3		25
Player 12	2	D,8	D,3	D,3	D,3	D,3	D,3	D,3	D,3	D,3		32
Player 13	3	D,8	C,1	C,5	C,5	C,5	C,5	C,5	C,5	C,1*	C,1	40
											Total Score	97

Player 11 Collude

Player Vs.	Game	1	2	3	4	5	6	7	8	9	10	Score
Player 8	1	C,5	C,5	C,5	C,5	C,5	C,5	C,5	C,5	C,5	C,5	45
Player 9	2	C,1	D,8	C,5	C,5	C,5	C,5	C,5	C,5	C,5	C,1*	44
Player 1	3	C,1	D,8	C,1	D,3	D,3	D,3	D,3	D,3	D,3	D,3	28
											Total Score	117

Player 12 Collude

Player Vs.	Game	1	2	3	4	5	6	7	8	9	10	Score
Player 10	1	C,1	D,3	D,3	D,3	D,3	D,3	D,3	D,3	D,3	D,3	25
Player 13	2	C,5	C,5	C,5	C,5	C,5	C,5	C,5	C,5	C,1*	D,8	41
Player 1	3	C,1	D,3	D,3	D,3	D,3	D,3	D,3	D,3	D,3	D,3	25
											Total Score	91

Player 13 Collude

Player Vs.	Game	1	2	3	4	5	6	7	8	9	10	Score
Player 12	1	C,5	C,5	C,5	C,5	C,5	C,5	C,5	C,5	D,8*	C,1	48
Player 2	2	C,5	C,5	C,5	C,5	C,5	C,5	D,8	D,3	D,3		44
Player 10	3	C,1	D,8	C,5	C,5	C,5	C,5	C,5	C,5	D,8	D,8	47
											Total Score	139

GROUP 2

Player 1 Collude

Round Number

Player Vs.	Game	1	2	3	4	5	6	7	8	9	10	Score
Player 2	1	C,5	D,8	C,5	C,1	D,3	C,5	D,1	C,5	D,3	D,1	36
Player 9	2	C,5	D,8	D,3	D,3	D,8	C,5	C,1	D,3	D,3	D,3	39
Player 7	3	C,5	D,8	D,3	D,3	D,3	D,3	D,3	D,3	D,3		34
Player 5	4	D,8	D,8	D,8	D,3	D,8	D,8	D,3	D,3	D,8	D,8	57
											Total Score	166

Player 2 Collude

Round Number

Player Vs.	Game	1	2	3	4	5	6	7	8	9	10	Score
Player 1	1	C,5	C,1	C,5	D,8	D,3	C,5	D,8	C,5	D,3	D,8	43
Player 3	2	C,1	D,8	D,3	C,1	D,8	D,3	C,1	C,1	D,3	D,3	29
Player 9	3	C,5	C,1	D,3	D,3	C,1	D,3	D,3	C,1	D,3	C,1	23
Player 8	4	C,1	D,3	D,3	D,3	D,3	D,3	D,3	D,3	D,3	D,3	25
											Total Score	120

Player 3 Defect

Round Number

Player Vs.	Game	1	2	3	4	5	6	7	8	9	10	Score
Player 4	1	C,1	D,3	D,3	D,3	D,3	D,3	D,3	D,3	D,3	D,3	25
Player 2	2	D,8	C,1	D,3	D,8	C,1	D,3	D,8	D,8	D,3	D,3	43
Player 8	3	D,8	C,1	D,3	D,3	D,3	D,3	D,3	D,3	D,3	D,3	30
Player 9	4	D,3	D,3	D,3	D,3	D,3	D,3	D,8	D,3	C,5	D,3	34
											Total Score	132

Player 4 Defect

Round Number

Player Vs.	Game	1	2	3	4	5	6	7	8	9	10	Score
Player 3	1	D,8	D,3	D,3	D,3	D,3	D,3	D,3	D,3	D,3	D,3	32
Player 7	2	D,8	C,3	D,8	D,3	D,3	D,3	D,3	D,3	D,3	D,3	37
Player 6	3	D,3	D,3	D,3	D,3	D,3	D,3	D,3	D,3	D,3	D,3	27
Player 5	4	D,8	D,8	D,8	D,3	D,8	D,8	D,3	D,3	D,8	D,8	57
											Total Score	153

Player 5 Collude

Round Number

Player Vs.	Game	1	2	3	4	5	6	7	8	9	10	Score
Player 6	1	D,3	C,5	D,8	D,8	C,1	C,1	D,3	D,3	D,3	C,1	35
Player 8	2	C,5	C,1	C,5	D,3	D,3	D,3	D,3	D,3	D,3	C,1	29
Player 1	3	C,1	C,1	C,1	D,3	C,1	C,1	D,3	D,3	C,1	C,1	15
Player 4	4	C,1	C,1	C,1	D,3	C,1	C,1	D,3	D,3	C,1	C,1	15
											Total Score	94

Player 6 Defect

Round Number

Player Vs.	Game	1	2	3	4	5	6	7	8	9	10	Score
Player 5	1	D,3	C,5	C,1	C,1	D,8	D,8	D,3	D,3	D,3		35
Player 9	2	C,5	C,5	C,5	C,5	C,5	C,1*	D,8	D,3	D,8	D,3	45
Player 4	3	D,3	D,3	D,3	D,3	D,3	D,3	D,3	D,3	D,3	D,3	27
Player 10	4	D,8	D,8	D,8	D,3	D,3	D,8	D,3	D,3	D,8	D,3	52
											Total Score	159

		Player 7				Collude						
		Round Number										
Player Vs.	Game	1	2	3	4	5	6	7	8	9	10	Score
Player 8	1	C,5	C,1	D,8	C,5	C,1	D,8	C,5	C,1	D,3	D,3	37
Player 4	2	C,1	D,3	C,1	D,3	D,3	D,3	D,3	D,3	D,3	D,3	23
Player 1	3	C,5	C,1	D,3	D,3	D,3	D,3	D,3	D,3	D,3	D,3	27
Player 5	4											
										Total Score		87

		Player 8				Collude						
		Round Number										
Player Vs.	Game	1	2	3	4	5	6	7	8	9	10	Score
Player 7	1	C,5	D,8	C,1	C,5	D,8	C,1	C,5	D,8	D,3	D,3	44
Player 5	2	C,5	D,8	C,5	D,3	D,3	D,3	D,3	D,3	D,3	D,8	36
Player 3	3	C,1	D,8	D,3	D,3	D,3	D,3	D,3	D,3	D,3	D,3	30
Player 2	4	D,8	D,3	D,3	D,3	D,3	D,3	D,3	D,3	D,3	D,3	32
										Total Score		142

		Player 9				Collude						
		Round Number										
Player Vs.	Game	1	2	3	4	5	6	7	8	9	10	Score
Player 1	1	C,5	C,1	D,3	D,3	C,1	C,5	D,8	D,3	D,3	D,3	32
Player 6	2	C,5	C,5	C,5	C,5	C,5	D,8*	C,1	D,3	C,1	D,3	38
Player 9	3	C,5	D,8	D,3	D,3	D,8	D,3	D,3	D,8	D,3	D,8	44
Player 3	4	D,3	D,3	D,3	D,3	D,3	D,3	C,1	D,3	C,5	D,3	27
										Total Score		141

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