Cooperation and self-regarding: How humans are influenced by others actions

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Abstract: The conflict between individual interests and good common is present in many different situations on living systems. How cooperation emerges it is very important to understand how behaves a lot of systems, as a city, a society or even an ecosystem. In this work we had purposed to have a look on how humans face this kind of situations. By analyzing the data of a social experiment, where 541 individuals played a social dilemma, we found that the actions of the people are influenced by the actions of their rivals, and this leads to a specific behaviour of the population. We expect that this work is going to help us to understand how cooperation emerges between individuals, and have a better approach to understanding the rules that obey the human societies.

I. INTRODUCTION

Complex systems[1] are defined by these systems formed by a set of agents, or parts that interact among them. A few examples of this are a city, a cell, an ant colony, a brain, a bunch of spins... and so on. In this kind of systems the characteristics of the interactions between the parts is at least as important as the characteristics of the agents. That is because from the interactions can arise properties of the whole system, called commonly as emergent properties[2]. In some of these systems the interactions are physical, like the electromagnetic interaction between water molecules (that leads to the emergent phenomena of the surface tension), but in so many other systems, like an ecosystem or a society, the nature of the interactions between agents it's better represented with tools provided by the game theory. Game theory[3] it is a branch of mathematics that studies the strategies and rules of the games.

One of the most popular games of the game theory is the prisoner's dilemma[4], in wich two players can choose between cooperation or defection. If both players cooperate both of them receive the same amount of reward R, but if one of them defects the defector gets a bigger reward T, and the cooperators get a smaller reward S. If both players choose to defect the both receive an intermediate reward P. In the prisoner's dilemma the reward parameters are always arranged with the following order: $T > R > P > S$. But the parameters P, R, S and T can be sorted in different ways, and then the game receive different names.

These games are a very interesting case of study since it contains the essence of the dilemma between good common and self interests, present in so many different scenarios, ranging from politics and economics to ecology. One example of a situation that is well represented with this kind of games is two competing companies that sell the same product. If both companies sell the product at the same price by mutual agreement we can say that both of them cooperate, but if one of them lowers the price more people are going to buy to them, with more reward for the defector company. Another example is the apoptosis of the cells[5], where cells kill themselves for the good common of the community. But if one cell chooses to defect, that means that it does not produce apoptosis, it lives more time, and gets more reward, but that causes cancer, and in the worst scenario the dead of all the other cells. Because all of this studying the behaviour of different individuals playing at these games can help us to understand the organization and dynamics of different communities. So, in this work we are going to analyze the results of a social experiment[6], were 541 people from different ages, places and genders played a game like the described previously. In this experiment people played between 15 and 20 rounds, every round with a different and unknown opponent, and with different values for the parameters S and T. P and R are always settled to 5 and 10 respectively. In a previous work[7], from the analysis of the actions of the people as a function of the parameters S and T, it has been found that there are 5 different strategies, or phenotypes (named as envious, trustful, optimist, pessimist and clueless), and every people belongs to one of these five phenotypes.

On the following sections we are going to see some patterns on the interactions between players, and build up a mathematical model to explain some of the global properties of our system. We will also make a computational simulation of our model, and compare it with the data.

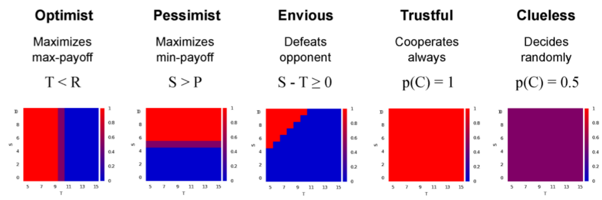

Figure 1. Actions as a function of S and T for the five phenotypes. Image taked from [7]

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II. THEORY AND RESULTS

A. The interactions

In this section we are going to explain the results that came up from the data analysis. But first we are going to explain in a more accurate way the game of the experiment. As we said, every participant of the experiment played between 15 and 20 rounds, every round with some different and unknown person. Before they could choose the action (that is cooperate or defect), we showed them the payment matrix (figure 1), where the columns are the opponent action, and the rows the self action. The S and T parameters varied randomly in every round, in the ranges [0,10] and [5,15] respectively, and as we said P and R was always settled to 5 and 10, respectively. The people that participated at this experiment was rewarded with a proportional amount of real money of what they won during the game.

$$\begin{array}{cc} & \begin{array}{cc} C & D \end{array} \\ \begin{array}{c} C \\ D \end{array} & \begin{pmatrix} R & S \\ T & P \end{pmatrix} \end{array}$$

Figure 2. Payment matrix

It seems reasonable that if a person cooperates, but their opponent defects, the first one on the next rounds will be forewarned against the others intention, and he will be more susceptible to defection. To check this what we did was calculate, from the experiment data, the rate of action changing after a round where the opponent gets a bigger reward (Gg), the same reward (Gi), and less reward (Gp), understanding action changing as different actions at consecutive rounds (table I). We can see from the table I that there's no significant differences among the three values of changing rate.

Gg	Gi	Gp
0.43 ± 0.03	0.42 ± 0.02	0.39 ± 0.03

TABLE I: Values of the Gg, Gi and Gp parameters. The error interval, on all this paper, was calculated at 99 per cent of confidence.

But, in every round the parameters S and T varies, so the game conditions can be so different between two consecutive rounds. So, we are going to consider that every round belongs to one of five different game zones, in function of the parameters S and T. This five game zones are all the possible permutations among the parameters R, P, S and T, and they are defined at equation (1). We are also considering that the actions of the same player are not correlated among different game zones (not a very accurate assumption, since the optimist and pessimist phenotypes have correlations among some of the game zones that can't be explained with our model, but in our case of study it is useful). Please note that since we make these considerations, at the game zones 1-4 the opponent getting a bigger reward corresponds to the situation of (C,D), where the C denotes the action of the subject, and D the action of the opponent. At the game zone 5 the opponent getting a bigger reward corresponds to the situation of (D,C). In general, for the game zones 1-4 the parameters Gg, Gi and Gp are the rate of action changing after a round at the situations (C,D), (C,C) or (D,D), and (D,C) respectively. At the game zone 5 the parameters Gg, Gi and Gp are the rate of action changing after a round at the situations (D,C), (C,C) or (D,D), and (C,D) respectively.

$$\begin{aligned} GameZone1 &: S < P < T < R \\ GameZone2 &: S < P < R < T \\ GameZone3 &: P < S < R < T \\ GameZone4 &: P < S < T < R \\ GameZone5 &: P < T < S < R \end{aligned} \tag{1}$$

After making this two considerations we can calculate a new changing rate values, understanding now the changing rate as different actions in two consecutive rounds at the same game. This results are shown at table II, for all the players, and for every phenotype. Please note that the trustful phenotype is the only one where $Gp > Gg$.

Also, at the table III are represented the values of Gg, Gi and Gp for every game, and we can see that the difference $Gg - Gp$ increases with the difference $T - S$ (Figure 4).

	Gg	Gi	Gp
All players	0.48 ± 0.04	0.28 ± 0.02	0.25 ± 0.03
Optimists	0.45 ± 0.07	0.30 ± 0.04	0.31 ± 0.08
Pessimists	0.57 ± 0.08	0.30 ± 0.04	0.34 ± 0.08
Envious	0.76 ± 0.09	0.18 ± 0.03	0.12 ± 0.03
Trustful	0.26 ± 0.06	0.31 ± 0.05	0.63 ± 0.13
Clueles	0.60 ± 0.10	0.42 ± 0.06	0.34 ± 0.09

TABLE II: Values of the Gg, Gi and Gp parameters for the different phenotypes.

Game zone	Gg	Gi	Gp
1	0.42 ± 0.06	0.37 ± 0.04	0.31 ± 0.05
2	0.54 ± 0.07	0.22 ± 0.04	0.18 ± 0.05
3	0.46 ± 0.08	0.37 ± 0.05	0.25 ± 0.07
4	0.37 ± 0.15	0.30 ± 0.10	0.35 ± 0.15
5	0.03 ± 0.06	0.13 ± 0.03	0.66 ± 0.12

TABLE III: Values of the Gg, Gi and Gp parameters for the different game zones.

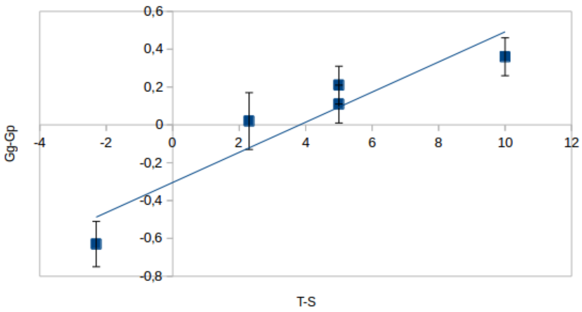

Figure 4. Gg - Gp vs. T - S.

B. Theoretical analysis

We are going to make in this section a theoretical analysis of the behaviour of the whole system, modeling the whole population as a dynamic system. First of all we'll suppose that every player have the same values of Gg, Gi and Gp, being these three values parameters of our system. We are also considering that the number of players tends to infinite, so we avoid statistical fluctuations, and in every round the opponent are selected randomly. Since we make this assumptions the probabilities of change the action for one player are:

$$\begin{aligned} p_{C\to\ D} &= fG_i + (1-f)G_g \\ p_{D\to\ C} &= fG_p + (1-f)G_i \end{aligned} \tag{2}$$

Where f are the fraction of the population that chose to cooperate. Please note that this analysis are only valid for the game zones 1-4 (to get the same analysis at the game zone 5 you just have to exchange Gg for Gp). Also we can get the difference of f between two consecutive rounds, as we can see at equation (3):

$$\Delta f = f_{t+1} - f_t = -f_t p_{C\to\ D} + (1-f_t)p_{D\to\ C} \tag{3}$$

Substituting the equations (2) at the equation (3), reordering terms, and defining $B = G_g - G_p$ (except at the game zone 5, where $B = G_p - G_g$) we get the following dynamic system:

$$\Delta f_{t+1} = Bf_t + (1 - B - 2G_i)f_t + G_i \tag{4}$$

We can find the fixed pints of our dinamic system imposing $f_{t+1} = f_t$, and we get the equation (5):

$$\Delta f = \frac{B + 2G_i \pm \sqrt{B^2 + 4G_i^2}}{2B} \tag{5}$$

Where the - sign corresponds to the attractor of the system. If we calculate the attractor with the parameters Gg, Gi and Gp founded at the data we get $f = 0,40 \pm 0,03$. By the other hand, if we calculate the average of the cooperation rate over the rounds 10-15 (rounds that are very near of the stationary state on our model) we get a value of $f = 0,46 \pm 0,03$.

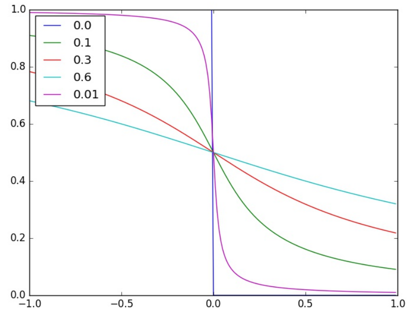

Figure 5. Here we represented the stationary value of the cooperation rate in function of B, for different values of Gi

We can see from the equation (5) that for positive values of B we get a cooperation rate of less than 0.5, but for negative values of B we get a cooperation rate of more than 0.5. This explain why at the game zones 1-4 ($B > 0$) we get less cooperation than at the game zone 5 (where $B < 0$), as we can see at figure 6.

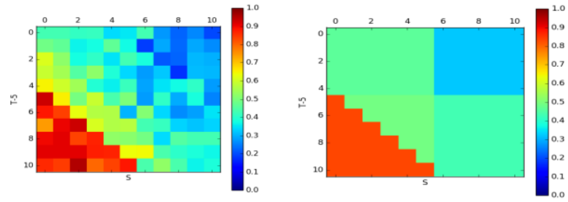

Figure 6. Cooperation rate as function of S and T parameters, calculated from the data (left) and from the equation(5) (right).

C. Computational analysis and phenotype emergence

We are going to make now a computational analysis of our system. For that we simulated N=100000 individuals, that played 15 rounds, every round with some other random opponent. Every individual have the same values of Gg, Gi and Gp. If we fix at 0.6, 0.3, and 0.2 the parameters Gg, Gi and Gp respectively we get the figure 7, where we represented the cooperation rate per round.

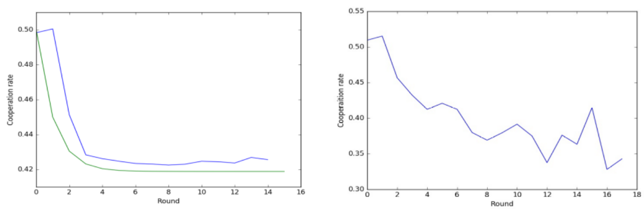

Figure 7. Cooperation rate per round, simulated and modelized (left), and calculated from the data (right).

As we said at the introduction there are five types or phenotypes of players, each one characterized by its actions in function of the S and T parameters. We are going to see how our model can explain the emergence of the envious and trustful phenotypes (optimist an pessimist phenotypes can't be explained with our model, since we assumed that the actions between different game zones are not correlated). For that we made the same simulation as before but using the values of table III for the parameters Gg, Gi and Gp, so we can represent the cooperation rate in function of S and T parameters. Also, a 10 per cent of the population have the Gg and Gp exchanged, representing the trustful players. In figure 8 we can see how the envious and trustful patterns emerge as the game progresses.

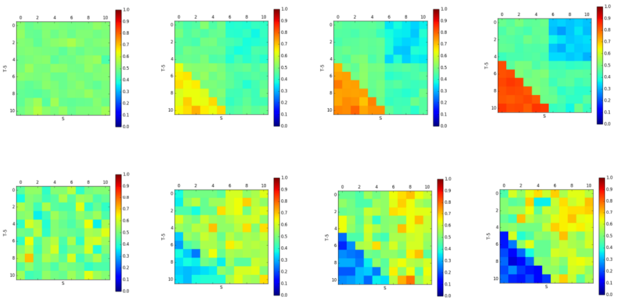

Figure 8. Emergence of the phenotypes envious (up) and trustful (down).

III. CONCLUSIONS

We are going to conclude this work with three conclusions about the experiment:

- First of all, we had seen that in this game the major part of the population tends to imitate the behaviour of the opponent when this one gets more reward than the subject, with a small fraction of the population (around the 0.1) with the opposite behaviour.
- The first conclusion leads to the second one: as the game progresses the cooperation rate of the population decreases until it reaches an stationary value.
- This kind of behaviour can explain the emergence of the trustful and envious phenotypes, as we had seen in figure 10. This model it is also compatible with the emergence of the clueless phenotype, since these players have a higher value of Gi, as we can see at table II, and that means more random actions, which is precisely the characteristics of clueless players.

Finally, we are going to make some observations for future research's. We had seen at figure 6 that the difference Gg-Gp increases with the difference T-S. It would be interesting to study in greater depth the relation between these parameters. It will also be interesting to find out how the optimist and pessimist phenotypes emerges in this game. One finally observation is that in this experiment the players never knew who player against, and this could be the reason of the decreasing cooperation rate. It would be interesting to find out how people behaves when they know their opponent.

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