Non-Blind Cooperation

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Abstract: This study investigates an altered version of the Prisoner's Dilemma, incorporating transparency and openness in players to examine non-blind cooperation. We introduce an openness parameter that, based on a probability, allows players to observe their opponent's intended move and adjust their strategy accordingly. Through an evolutionary model incorporating iterated pairwise interactions to determine the reproductive fitness of different strategies in the face of additional information, we identify distinct cooperation and coordination thresholds. We demonstrate that low benefits paired with increased openness can reduce coordination and allow exploitation to dominate. Moreover, higher benefits and moderate openness induce a shift toward cooperative equilibrium. We observe the effect of differing heights of such cooperation and coordination thresholds on the system's behavior. This work extends evolutionary game theory by incorporating strategic foresight into cooperation dynamics.

Introduction

The dynamics of strategy evolution are mostly studied in infinite and finite populations. Infinite populations rely on deterministic equations while finite populations rely on stochastic methods to measure evolutionary stability and fitness within evolutionary games (Sandholm 2010, Taylor et al. 2004). For example, in "Emergence of cooperation and evolutionary stability in finite population" Nowak investigated the favorability/probability of favorability of one strategy for the Prisoner's Dilemma in a finite population. They determined a condition for selection favoring this strategy and used a stochastic game model to test the likelihood of it holding in various finite populations. Moreover, in "Fitness and evolutionary stability in game theoretic models of finite populations" by Geoff Wild and Peter Taylor, they investigated two types of evolutionary games on finite populations, one using immediate gain, and another "incorporat[ing] the possibility that any strategy with non-zero RF can persist over evolutionary time by genetic drift" (Wild and

Taylor 1). They concluded that there is an equivalence between reproductive fitness and fixation probability. Nowak's paper validates the use of stochastic games to test the favorability of certain strategies among finite populations and Wild and Taylor show that multiple strategies can exist among a finite population.

Something common to both papers and most of the previous research on cooperation games is the lack of a mutual understanding between players about their potential strategies. In the Prisoner's Dilemma used in Nowak's paper, players have no intuition of their opponent's next move. The players are essentially blind in each pairwise contest, so strategies that form are based on risk-reduction and memory. But what would happen if we introduced an addition to the set-up of the game that allowed for more strategic opportunity? When a TFT mutant was tested in a finite population of ALLD players, the population shifted towards the TFT strategy (Nowak et al. 2004).

Thus, perhaps introducing another layer to the game could reveal the emergence of new favorable strategies. This method of simulating cooperation fails to reflect the abundance of information provided by two people in a real interaction. Humans, either unintentionally or intentionally, always emit interpretable behaviors in interactions. Someone who gives smaller signs that they are willing to do something or has begun in a process to start cooperating (though not yet having gone through with it) may induce more cooperation within social situations or be exploited more easily. Capraco et al from Middlesex University investigated a related example within a standard prisoner's dilemma model where players were set to believe their choices might be observable (Capraco et al 2019). Their study found that such a perception can increase cooperation due to the risk of being detected when defecting.

In this study, we propose adding another layer to the existing Prisoner's Dilemma structure using an indicator for the behavior of each player. This indicator can limit the success of defection. For example, a player who was planning to defect will be thwarted by their opponent knowing this fact and choosing to defect in response so they gain less. Similarly, a player who knows their opponent will cooperate can increase or decrease the likelihood of exploitation. This could lead to a machiavellian type of coordination, as it is mutually beneficial to say "I'll cooperate if you do." However, it may also open up doors for betrayal and false security, making this addition much more nuanced. With this, we aim to analyze the evolutionary effects of such an indicator to see whether or not it encourages or discourages cooperative behavior among finite populations.

Methods

We used a standard prisoner's dilemma set up with pairwise interaction among all players in a finite population (Dyer & Mohanaraj 2011). Our strategy space consisted of tit-for-tat, exploitation strategy, and cooperation strategy. Each player was given the initial strategy of Tit-for-Tat (TFT) with a probability of swapping to one of the two information strategies.

An overall process line is as follows

→ The population is initialized with a mix of cooperators and defectors

→ Agents pairwise interact, accumulating payoffs. Openness modulates strategy updates.

→ Payoffs determine reproductive success, with mutations introducing strategy switches.

→ The simulation ends if cooperation reaches fixation (100% or 0%) or after 4,000 generations.

The first iteration of the game would be played with each player using a tit-for-tat strategy, thus a 50\50 chance to cooperate or defect. The following iteration would call upon a parameter o, the probability that each player can see their opposing player's initial move and adjust accordingly to adopt either cooperation strategy or exploitation strategy depicted in Table 1. The next iterations would use either general TFT if the probability was not achieved, or their updated strategy if it was.

Table 1:

Information	None (first round)	C	D
Cooperation Strategy	TFT	C	D
Exploitation Strategy	TFT	D	D

At the end of each 50 rounds the pay-offs of each player are determined by a general Prisoner's Dilemma pay-off matrix (Hilbe et al 2018). Note that the cost *c* was fixed at 2 to guarantee positivity as the benefit *b* was varied.

	C	D
C	b-c(+c)	-c (+c)
D	b (+c)	0 (+c)

The evolutionary process was modeled as a frequency-dependent Moran process with selection and mutation (Norman 2020, Allen et al 2016). At each generation, agents' reproductive success was determined by their cumulative payoffs from pairwise interactions. A random agent was selected for removal (death). To replace it, another agent was chosen with probability proportional to its total payoff (fitness). This ensured that agents with higher payoffs were more likely to reproduce. With a mutation probability (pmut), the offspring adopted the opposite strategy (cooperator ↔ defector), introducing stochasticity into the population. Simulations ended early if cooperation reached fixation (0% or 100% of the population) or after completing all 4,000 generations.

It is important to note that our model does not include errors in the information provided, thus strategies will always execute perfectly and information is transferred reliably, which could potentially lead us to overestimate or underestimate the cooperation in these populations.

Results

We ran the simulation on 200 timesteps for 24 parameter combinations with 20 trials. The parameters we varied were the benefit: b = 3 and b = 6, initial cooperators: pc0 = .05 and pc0 = .15, and openness: *o* = 0,.1,.3,.5,.7,.9. We chose to increment our openness variable this way as smaller changes would have been insignificant to the probability. The following figures represent the proportion of coordinators across these varying parameters.

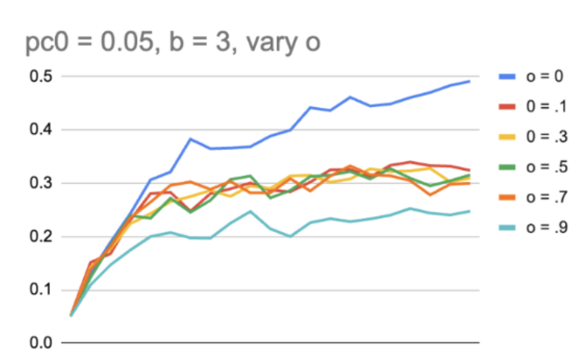

Figure 1

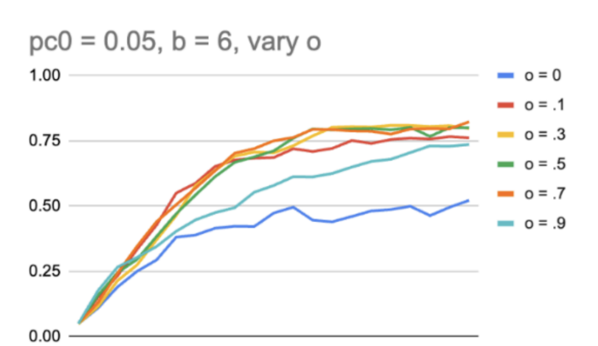

Figure 2

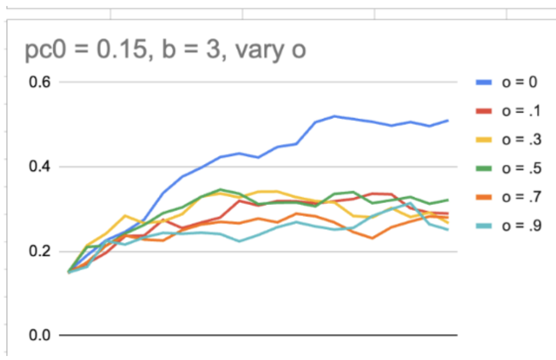

Figure 3

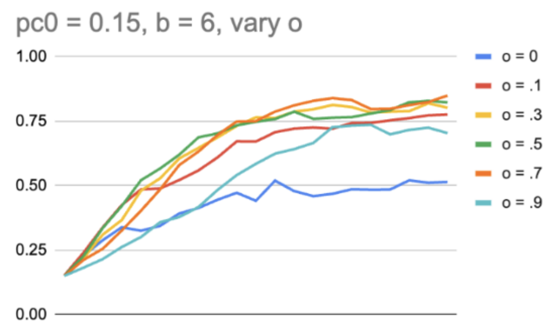

Figure 4

Figure 1 shows that for low initial cooperators and low benefits, the system reaches equilibrium at relatively low levels of coordination. The variance of openness is insignificant as the population will always reach an equilibrium, but the equilibrium itself is higher for lower openness. This suggests that higher openness with lower benefits leaves more room for exploitation strategies to hinder coordination.

In contrast, Figure 2 shows a shift with higher benefits. A clear threshold emerges as the coordination drastically increases as openness increases to .3-.5, then accumulates past .5. This can be seen as a cooperation threshold where sufficient benefit and moderate openness allow cooperation to dominate. Beyond and near o = .75, the coordination stabilizes, perhaps highlighting a non-linear relationship between benefit and social influence.

Figures 3 and 4 show that the initial proportion of cooperators has an insignificant impact on the coordination levels, reinforcing the stronger relationship of b/c and openness with coordination. Figure 3 shows a similar equilibrium to Figure 1 (modest equilibrium), reinforcing the claim that initial cooperation is insufficient to impact coordination significantly.

However, Figure 4 shows a similar threshold to Figure 2 but with more breadth. If o exceeds .1, the system rapidly transitions to higher coordination levels and like in Figure 2, stabilizes around .75. The main difference lies in the speed of the transition and the lower threshold for cooperation to dominate. This result suggests that a higher proportion of initial cooperators can indeed induce a higher level of coordination so long as it is paired with strong cooperative incentives and the openness is moderate.

Discussion

With this, we can analyze the behaviors of the system by looking at the coordination threshold versus the cooperation threshold. If CPT < CDT, the system heads towards a “Machiavellian Zone” where cooperation exists but global coordination fails due to the dominance of strategic exploitation. This is particularly reinforced by Figure 3, where the lower initial cooperator proportion influences the possibility of lasting population-wide coordination with low benefit even despite openness. Moreover, if CPT > CDT, we see global coordination become easier to achieve than cooperation as it will follow from cooperation.

The influence of *o* varies between different settings. With low benefits, increasing *o* depresses coordination (Figures 1 and 3) as the exploitative strategies dominate. However, with higher benefits, we see that *o* can increase coordination once the system crosses the cooperation threshold.

The scope of these results is limited for various reasons. For one, our parameter *o* and the values we used to vary it in the simulation could be too high to represent real life. Humans can act one way and perform another, which is also not represented in our model. To increase the accuracy of results, a probability of false information could be applied to create random disinformation. Perhaps this could be implemented purposefully as a strategy as well. This, paired with a reputation/trust system would potentially be more reflective of real life and produce more significant results.

Moreover, as stated previously in the methods section, the model does not take into consideration any error in the information provided to the players by which they update their moves and strategies. This is problematic as it implies that when the probability o is achieved, the player becomes clairvoyant, which is not reflective of real-life situations in which reading errors occur frequently. This could potentially skew the results toward coordination.

Future studies should take into consideration the multifaceted nature of human interaction and introduce more parameters, a larger strategy space, and potentially something similar to the reputation system mentioned previously.

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