Encouraging Defection in Cooperation Models

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ABSTRACT

Computational models that simulate in-group/out-group cooperation dynamics have shown that ethnocentrism, a preference for one's own kind, often emerges as a dominant strategy among others. A lot has been said about interactions among out-groups, so this paper seeks to explore in-group dynamics by analyzing the conditions that are favorable for defectors. Results indicate that although no *dominant* strategy emerges, fewer 'countries' and a smaller lattice size promotes the proliferation of free riders (agents that don't cooperate with their in-groups) in comparison to larger grids with more countries. However, simulations in which there are no in-groups or no out-groups promote cooperative agents.

INTRODUCTION

Studying patterns of cooperation among in-groups and out-groups suggests that agents will cooperate with each other despite detrimental costs to the self. (Shultz & Hartshorn & Kaznatcheev 2009) However, it's not blind cooperation, but rather strategic cooperation (trusting members of the in-group but not out-groups) that has been shown to dominate through evolutionary processes (Hammond & Axelrod, 2006). Different studies have focused on characterizing aspects of ethnocentric dominance, from observing strategy frequency as a world populates to saturation (Shultz et al. 2009), theorizing whether humanitarianism (agents that help all indiscriminately) fares poorly against ethnocentrics because they have difficulty suppressing free rider agents (Hammond & Axelrod, 2006) or because ethnocentrics exploit their unconditional cooperation (Shultz et al. 2009). A lot of focus has been directed outgroup interactions; defectors take advantage of cooperators, but I am interested in exploring in-group dynamics, where ethnocentrics and humanitarians are vulnerable to exploitation by selfish and traitorous agents.

INITIAL MODEL

The agent-based simulation proposed by Hammond and Axelrod (Hammond & Axelrod, 2006) is the standard model on which previously mentioned extensions, and the following report, are based on. A toroidal lattice is populated by agents who interact with their four von Neumann neighbors. Agents have identifiable tags used to distinguish in-groups and out-groups. Agents with the same tag consider each other part of the in-group, and all others belong to the out-group. Agents employ two strategies of cooperation with their neighbors; they either cooperate or defect. 4 strategies arise from the application of these two behaviors towards in-groups and out-groups, illustrated in the table below. 0 represents defection and 1 represents cooperation.

Strategy	In-group	Out-group
Traitor	0	1
Selfish	0	0
Ethnocentric	1	0
Humanitarian	1	1

Table 1.

The initial simulations were modelled on a 50x50 lattice with 4 tags. The simulation begins with an empty lattice. The four stages that occur in each cycle are summarized below.

1. ***Immigration***: A randomly generated agent (with a random tag and strategy) is placed in an empty spot on the grid.
2. ***Interaction***: Every agent on the grid engages in one game of Prisoner's Dilemma (described below) with each of its neighbours. The payoff from these games affects the reproductive potential of the agent (which is initialized to a 12% chance of reproducing)

3. ***Reproduction***: After shuffling the agents on the grid to eliminate spatial advantages, each agent is given a chance to reproduce with a probability equal to the modified reproductive potential. The offspring is placed in an empty adjacent site and is a clone of the agent (it has the same tag and strategy), although it can be subject to mutation.
4. **Death**: Each agent has a 10% chance of dying.

Prisoner's Dilemma

The prisoner's dilemma (PD) is a useful framework for modelling inter-group cooperation (Kaznatcheev & Shultz 2011). In this game, autonomous agents choose whether to cooperate with, or defect from, their partners, without knowledge of the others' decision. Four scenarios arise. Either both cooperate, both defect, or one cooperates while the other defects. A numerical value has been assigned to the benefit of receiving cooperation and the cost of being cooperative. The following table outlines the computed values that will then be added to (or subtracted from) the reproductive fitness of the agents involved.

		Agent B	
	Strategy	**Cooperate**	**Defect**
Agent A	**Cooperate**	A: 0.02 B: 0.02	A: - 0.01 B: 0.03
	Defect	A: 0.03 B: - 0.01	A: 0.00 B: 0.00

Table 2.

As of a result of these interactions, cooperation is costly to the individual but beneficial to the collective, whereas defection is beneficial to the individual, who stands to gain at best the highest benefit, or at worst, no net gain or loss.

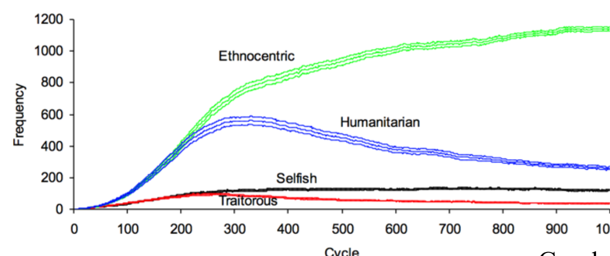
RAISING QUESTIONS

The following table represents the possible interactions for strategies among in/out-groups in terms of possible points gained/lost from a PD game (in % instead of decimal value, for reading ease). This is the table that sparked the inquiry driving this paper. In-group strategies are denoted by the same colour (black) whereas out-group strategies are denoted by the colour red.

	selfish	traitor	ethnoc.	humanit.	selfish	traitor	ethnoc.	humanit.
selfish	0	0	3	3	0	3	0	3
traitor	0	0	3	3	-1	2	-1	2
ethnoc.	-1	-1	2	2	0	3	0	3
humanit.	-1	-1	2	2	-1	2	-1	2

Table 3.

The traitor and ethnocentric rows have been highlighted to show that according to this table, it seems like ethnocentric and traitorous agents have the same possible PD outcomes but reversed for in-groups and out groups. Can traitors be seen as identical to ethnocentric agents of a different tag? Throughout this paper we will discuss why that is not the case. It also seems like selfish traitors can only stand to gain from their interactions. However, given the following graph of mean population frequency for evolving strategies (Shultz et al. 2009) with 4 tags over 1000 cycles, ethnocentrism distinguishes itself as a dominant strategy, whereas selfish and traitorous agents trail far behind in numbers.



Graph 1.

Clearly the above table is misleading. First of all, the proportion of interactions with in-group and out-group agents is not equal, as an agent will have only one in-group but 3 out-groups to interact with. Furthermore, even the proportion of interaction between strategies is not equal. At cycle 900 in a world emulating the above graph for example, the probability an ethnocentric agent will encounter another ethnocentric agent is much higher than its probability of encountering a traitor.

This raises the question, however; what would happen if there were fewer out-groups to interact with? Would traitors become more prevalent? Another issue preventing the propagation of traitors and selfish agents is that they benefit from in-group interactions with agents bearing *different* strategies. Increasing their population therefore relies on the probability that they encounter such agents. In a sparsely populated world, that probability is low.

Problem: More out groups than in groups are disadvantageous for traitors
Solution: Decrease number of tags. Also look at what happens as tags increase (for symmetry).

Problem*:* Traitor populations have difficulty growing at the initial stage
Solution*:* Decrease size of grid, increase chance of interaction with other kind of strategies

The cost-benefit expectations of the Prisoner's Dilemma raise the question; why *aren't* people more uncooperative? (Shultz & Hartshorn & Hammond 2008) What conditions promote more defecting/traitorous behaviour? In this paper, I hypothesize that decreasing the size of the world and the number of tags will increase the proportion of traitors.

METHOD

For this study, the simulations presented by Shultz et al. (2009) are reanalyzed and compared to simulations using a smaller lattice size and variable number of tags. Data from the 'run' and 'run-all-strategies' functions will be graphed using two lattice sizes (50x50, 10x10), and 5 tags values (1, 2, 4, 8, 10000). The 'run-all-strategies' function records the number of agents for each of the four strategies across 1000 evolutionary cycles. The 'run' function records the average behavior proportions (cooperate /defect) and average strategy proportions (selfish, traitor, ethnocentric, humanitarian) over the last 100 cycles in a 1000 cycle run. The structure of the model remains the same, so the only code that was changed was done so to accommodate 1 and 10000 tags. To implement the strategies described below, the optional parameters regarding the number of tags/size of lattice were used.

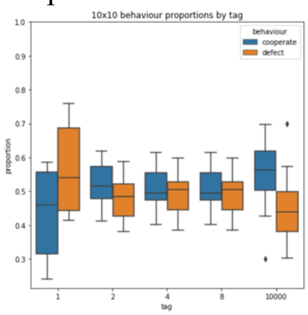
The following will describe the methods /reasoning behind the chosen parameter values:

1 tag: This represents no out groups (all agents belong in the same in-group). According to Table 3, humanitarians and ethnocentrics have the most to lose from this deal whereas selfish and traitorous agents would have the most to gain. In the code, the following modifications were made: when creating a new immigrant ('immigrant' function), the tag is no longer set to a random number, it's automatically equal to 1. When cloning the agent ('clone' function) the tag is no longer subject to mutation (as there are no other tag options to mutate to)
2 tags: Half the original number of tags. One in-group, one out-group.
4 tags: Replicate original number of tags.
8 tags: Double number of original tags.
10,000 tags: 10,000 tags implemented to simulate an 'every man for himself' environment. For example, as there are only 100 possible agents in a 10x10 lattice, but 10,000 possible tags, so it is likely that there will be many unique tags, approximating a scenario in which there are many out-groups and no/very few in-groups. To ensure the 'uniqueness' of each agent, the tag mutation probability of offspring is changed from 0.005 to 1, so there is a 100% chance the offspring has a different tag than its parent. Mutation of in-groups/out-groups is kept at 0.005.

RESULTS

Figures 1 and 2 depict the average behavior proportions by tag for the last 100 cycles in a 1000 evolutionary cycle run for the 10x10 and 50x50 worlds respectively. Their results suggest that an increase in lattice size results in an increase in discrepancy between cooperation and defection.

On a large grid, more tags promote more defection and less cooperation, except at the extreme where every agent more-or-less has a different tag. In that case, cooperation is again seen in higher proportions. On a small grid, defection is expressed more in a world without any outgroups and discouraged most (compared to cooperative behavior) in a world with only outgroups. Does this mean extreme diversity promotes cooperation?



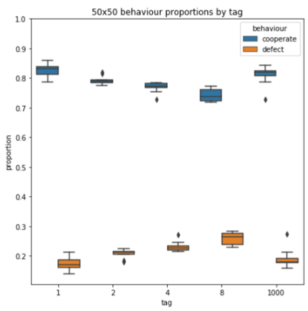
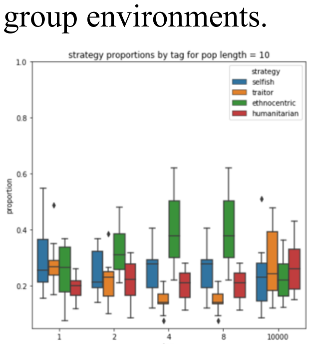


Figure 1. Figure 2.

Figures 3 and 4 depict the average strategy proportions by tag for the last 100 cycles in a 1000 cycle run, for the 10x10 and 50x50 worlds respectively. In both worlds, an increase in number of tags results in an increase in ethnocentric exhibition and a decrease in traitors, *except* in the every-man-for-himself scenario (EMFH). In EMFH, traitors and humanitarians are highly expressed. When there are no in-groups, traitors and humanitarians are both agents that cooperate with everyone, whereas selfish and ethnocentric agents cooperate with no-one. This is a fascinating result that one again suggests cooperation is supported in highly diverse, no in-group environments.



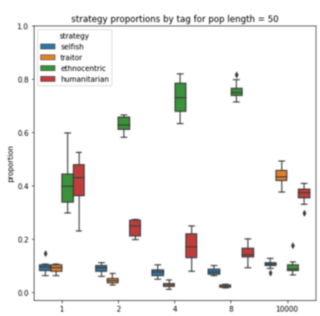


Figure 3. Figure 4.

Figures 5 and 6 depict the frequency of each strategy over 1000 evolutionary cycles, for lattice of size 10x10 and 50x50 respectively. No dominant strategies appear in in the small lattice, but ethnocentrics and humanitarians dominate when there are no out-groups. In this case, ethnocentrics and humanitarians are the only cooperating agents on the board.

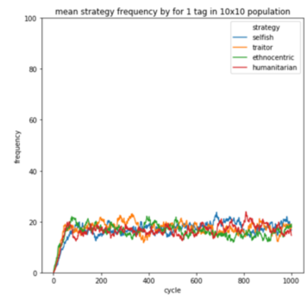
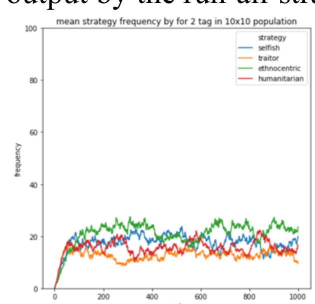


Figure 5. Figure 6.

Figures 7 and 8 depict the frequency of each strategy over 1000 evolutionary cycles, for lattice of size 10x10 and 50x50 respectively. The results are not very interesting compared to the other graphs, but I included them because this project started with a curiosity about agent behaviour when there is one in-group and one-out group. On a large lattice, the familiar curves are starting to be made evident, whereas on the small lattice, although ethnocentrism seems to be more frequent overall, there doesn't seem to be a consistently dominant strategy. This is confirmed by the significance of dominant strategy tests output by the run-all-strategies function.



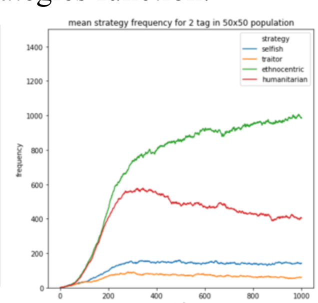


Figure 7. Figure 8.

Figures 9 and 10 depict the frequency of each strategy over 1000 evolutionary cycles, for lattice of size 10x10 and 50x50 respectively. Figure 9 does not reflect the strategy proportions seen in figure 3. Why is that? Possible explanations include the fact that the data is averaged over 10 worlds and may not have sufficient data points to offer repeatable results. Ideally, next time I would have included +/- 1SE in the graph for a more accurate representation of the. Also, Figure 9 looks at the *mean* strategy *frequency*, whereas Figure 3 displays the *median* strategy *proportion* just for the last 100 cycles. Figure 10 *does* however reflect the results shown in Figure 4, where traitorous and humanitarian agents *far* out perform selfish and ethnocentrics.

Figure 9.

Figure 10.

For the complete python code/all the graphs that were left out, please visit the following link: https://github.com/cisaic/ethnocentrism-psyc315

DISCUSSION

The fascinating result to come out of this project is the fact that although I was initially interested in the implications of *few* tags, I discovered along the way that *many* tags also generated interesting data. Everyone being from the same country and everyone being from a different country results in the same thing; cooperation is encouraged. At small values, increasing the number of 'countries' did encourage defection/ethnocentrism. A high prevalence of defection correlates with the presence of ethnocentrism, particularly when ethnocentrics make up a high proportion of the population. My initial prediction was correct in that there were proportionally more traitors in 2-tag simulation than 4-tag, and more in 4-tag than 8 tag simulations. For no out-group/no in-group scenarios though, it doesn't make sense to talk about traitors and ethnocentrics, because each agent effectively only employs one strategy. In these scenarios, it makes more sense to talk about defectors and cooperators. In a situation where agents may ONLY choose one strategy, cooperation wins out for all. The way cooperation works is that cooperation offers a benefit to the self on some occasions but benefits the partner on all occasions. Defection, on the other hand, offers a high possibility for individual gain but partner never flourishes. Traitors have a high chance of individual gain, but a low chance of collective gain, which is why they fare poorly in simulations with a moderate number of tags. It's very interesting to note, however, that an Every-Man-For-Himself scenario would *not* promote defection, as one might intuitively assume, but rather cooperation. Between cooperating agents, they *both* increase each other's reproductive potentials to ensure higher populations.

Initial models presented a pessimistic view of cooperation dynamics in which strategies that promoted keeping to one's own kind were favoured, but this study shows that perhaps viewing everyone as different or everyone as the same to oneself might help promote cooperation.

TO DO

Future improvements/ extensions to the method:

- Include +/- 1 Standard Error for frequency/cycle graphs to provide more accurate reading of data distribution, and instead of frequency, graph proportion instead
- Improve EMFH scenario: my implementation approximates the scenario in which every agent has a unique tag, but does not ensure it.

Interesting questions to pursue further:

- What would the strategy distribution look like on a grid with a high number of countries, but few enough so that there can still be in-groups? For example, on a 10x10 board, look at 20-50 countries.
- I neglected the measures for statistically significant dominance, but it would be interesting to graph them per cycle
- Graph behaviour proportions towards in-groups vs out-groups.

- What conditions are optimal to promote humanitarianism? The answer would be conditions in which cooperation is optimal across in-group and out-groups, but what would that look like? A preliminary run that changes cost/benefit values for the PD game shows that increasing the cost results in increased selfishness and increasing the benefit results in an increase in cooperation. When cost is equal to benefit, the following strategies do best to worst: selfish > ethnocentric > traitor > humanitarian. This list is also ordered from most to least number of defection strategies. It seems like difficult environments where one could stand to gain more than they would lose encourages cooperation. Please keep in mind these are just qualitative estimates based on a quick simulation.
- I'd like to question the methods used to calculate gains/losses in the PD game. If we were to change the world 'defect' to 'destruct', the choice to 'destruct' by both parties might not result in a net gain of 0. Imagine a Nuclear Dilemma instead of a Prisoner's Dilemma. How would this change expression of cooperation? Would this encourage a high expression of cooperation? Perhaps even humanitarianism?
- In this study we make the assumption that the relation of every agent to their tag is binary; they either belong to it or they don't. How would a simulation look where there are multiple tags, and agents belong to them in degrees? Is this just adding unnecessary complexity to the model?
- All agents behave according to predetermined strategies. Would ethnocentrism emerge if agents were allowed to 'learn' based previous experience with different tags? Would we see the formation of alliances (countries that cooperate with each other but not others – kind of like an outer in-group).
- Look at size of countries relative to the grid; is there an optimal country size? Do countries have similar sizes, or does one country dominate? Why?

References

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