FINAL PROJECT

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PSC 120

Introduction

Through this model, we are trying to analyse how payoff matrices for the prisoner's dilemma interact with strategies, space, movement, groups, and local reproduction. In this model and report we bring up various terms such as naïve cooperator and defector, and different strategies such as PAVLOV, TFTM, etc. Let us go through the definitions of these terms and strategies before proceeding with the experiments-

NAÏVE DEFECTOR/COOPERATOR: In any basic model, populations consist of two types of agents: cooperators, and defectors. Cooperators, as the name suggests, always cooperate, while defectors always defect. We retain those agent types in our model and call them 'naïve cooperators' and 'naïve defectors' respectively.

WALKAWAY: Through this strategy, if an opponent cooperates, a given agent will stay with that opponent and continue to cooperate with them. If the opponent defects, the agent will "punish" the opponent by moving away from them in a random direction for the next round rather than playing again.

TFTM (Tit-for-tat mobile): In this strategy, agents move around till they find an opponent. Agents then match the strategy of their opponent from their last encounter on each round of the prisoner's dilemma. If the opponent cooperated, the agent will cooperate, and vice versa if they defect on their next encounter with each other.

PAVLOVM (Pavlov mobile): The Pavlov strategy starts off with agents cooperating on the first round of the prisoner's dilemma. When agents interact and move around, if their opponent cooperates, then they continue to cooperate. However, if the opponent defects, Pavlov immediately switches its behavior to retaliate and defect back.

As for our model, in the prisoner's dilemma, the quantitative relationships for the cooperative payoff (R), the payoff for defecting when playing a cooperator (T), the sucker's payoff when playing a defector (S), and the defectors payoff (P) are: T > R > P > S, and the default payoffs we have been using are 5(T) > 3(R) > 0(P) > -1(S).

My team and I conducted simulation experiments based on the prisoner's dilemma, changing certain quantitative payoffs in our model to create specific conditions for each experiment to see how it would affect or influence cooperation.

1. Experiment 1

Introduction & Methods

Through Experiment 1, we are trying to investigate the relationship between cooperators and defectors. The variable that we are varying in Experiment 1 is the lethality, 's'. We set s = -1 for nonlethal conditions, and s = -100 for lethal conditions. We compare these two payoff conditions to find which conditions cooperators do better in.

For this experiment, 1000 agents (900 walkaway cooperators, 100 defectors) were placed on a 75x&5 2D grid and allowed to move around. When they encountered another agent, each pair played a round of prisoner's dilemma. As mentioned earlier, the sucker's payoff was set to either -1 or -100. Agents were additionally subject to the following four conditions - *(1) LocalReproduction = false, groups = true, (2) LocalReproduction = true, groups = true, (3) LocalReproduction = true, groups = false, (4) LocalReproduction = false, groups = false*. Each simulation was repeated 5 times.

Results

Below are the graphs from the data that was generated.
Fig 1.1, 1.3, 1.5 and 1.7 are the graphical results from when we set s = -1 (nonlethal), and Fig 1.2, 1.4, 1.6 and 1.8 are from when s = -100 (lethal).

Condition 1: LocalReproduction = false, groups = true

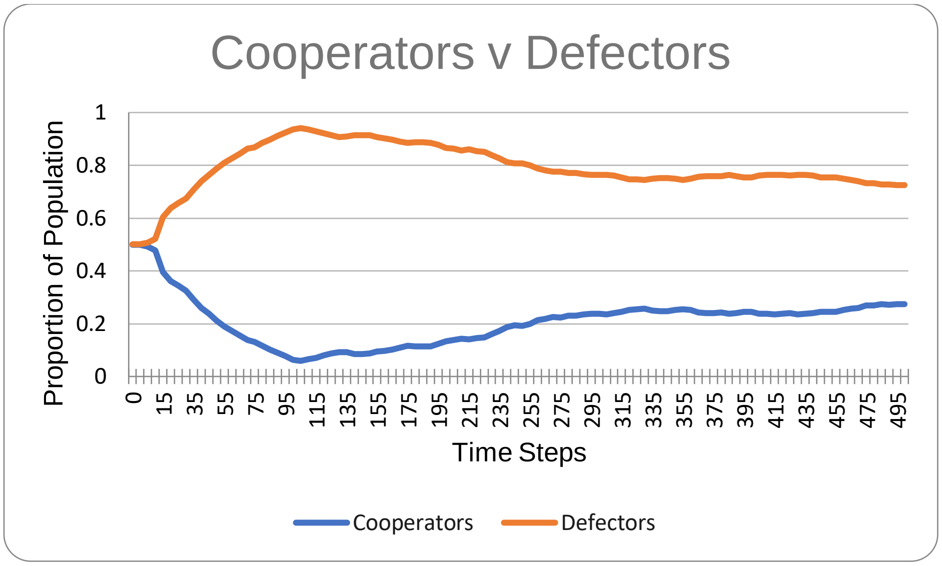


Fig 1.1

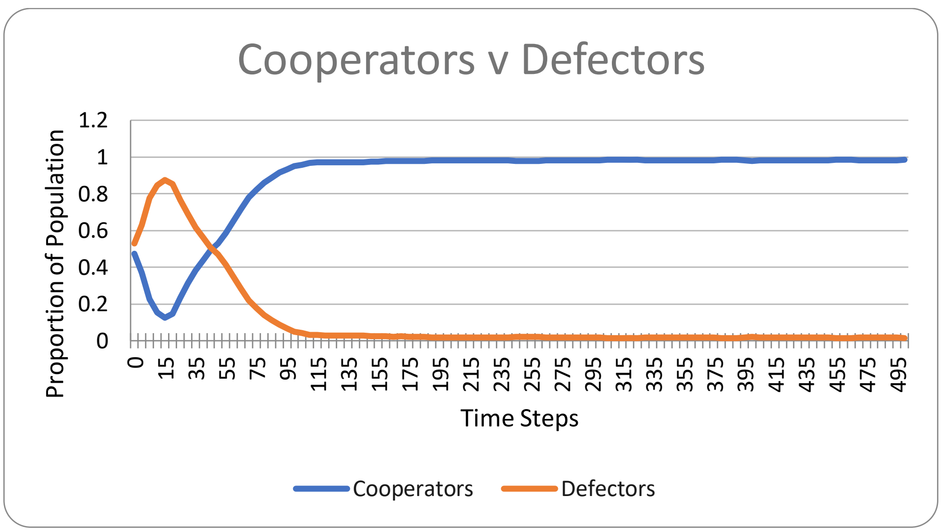


Fig 1.2

Condition 2: LocalReproduction = true, groups = true

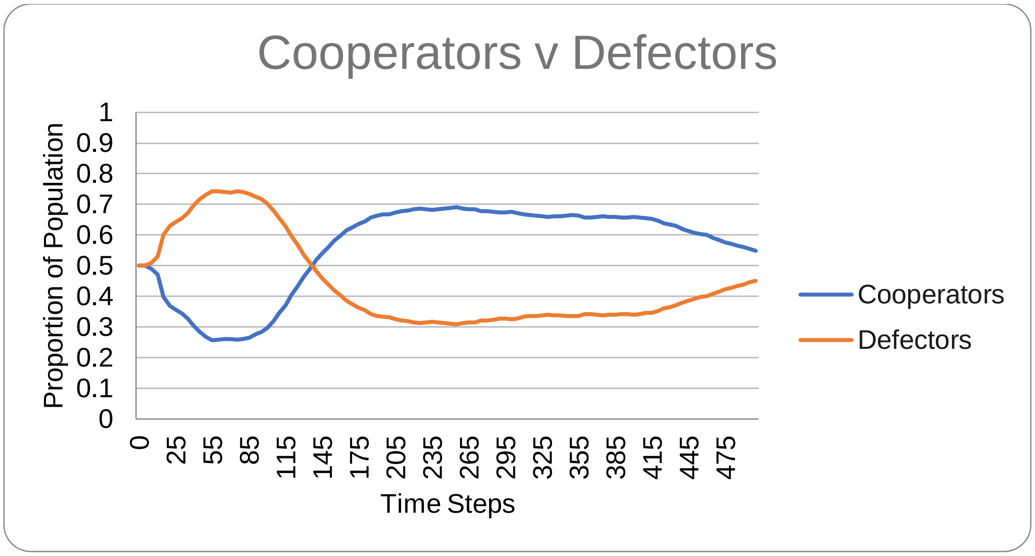


Fig 1.3

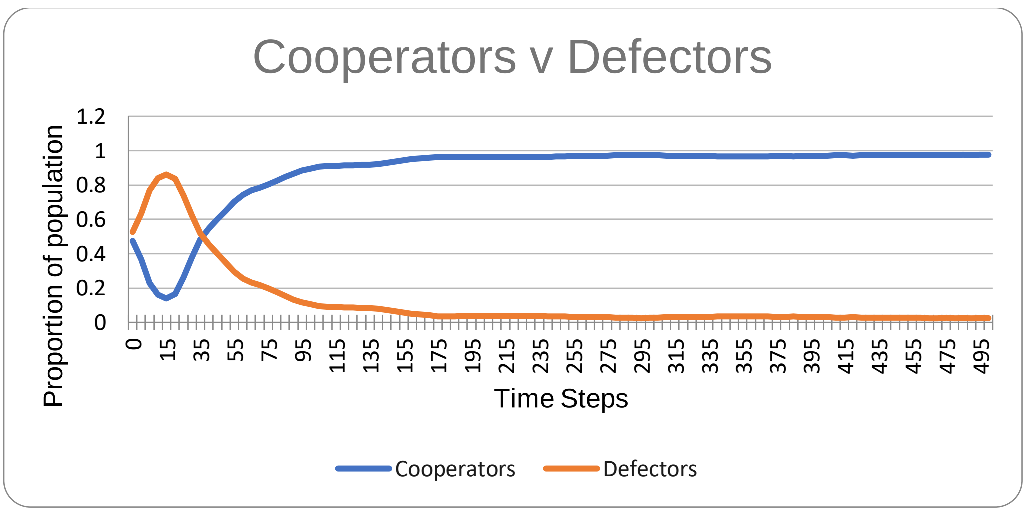


Fig 1.4

Condition 3: LocalReproduction = true, groups = false

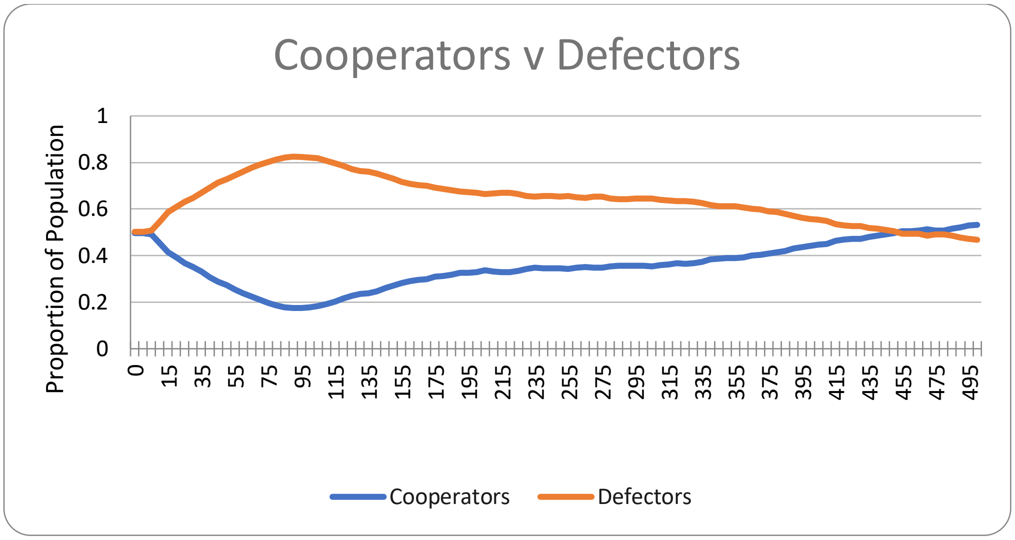


Fig 1.5

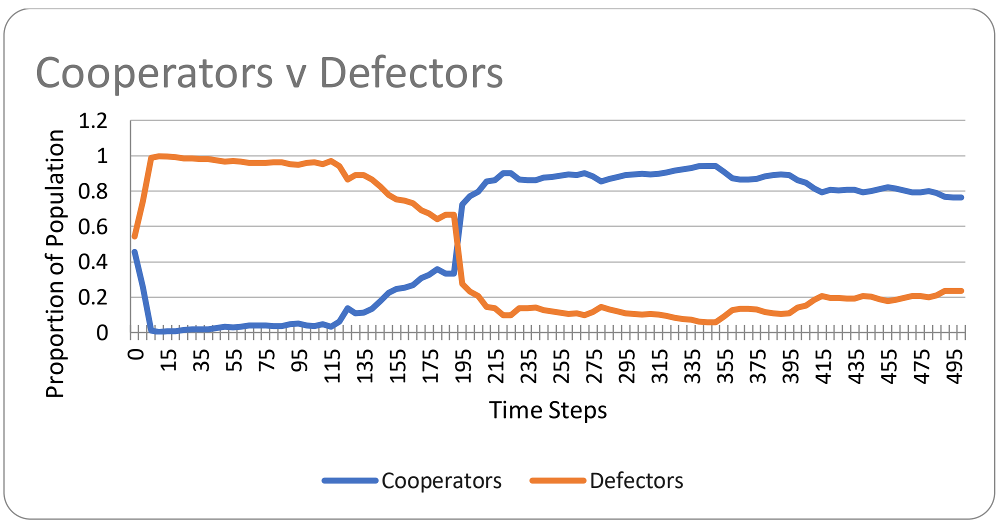


Fig 1.6

Condition 4: LocalReproduction = false, groups = false

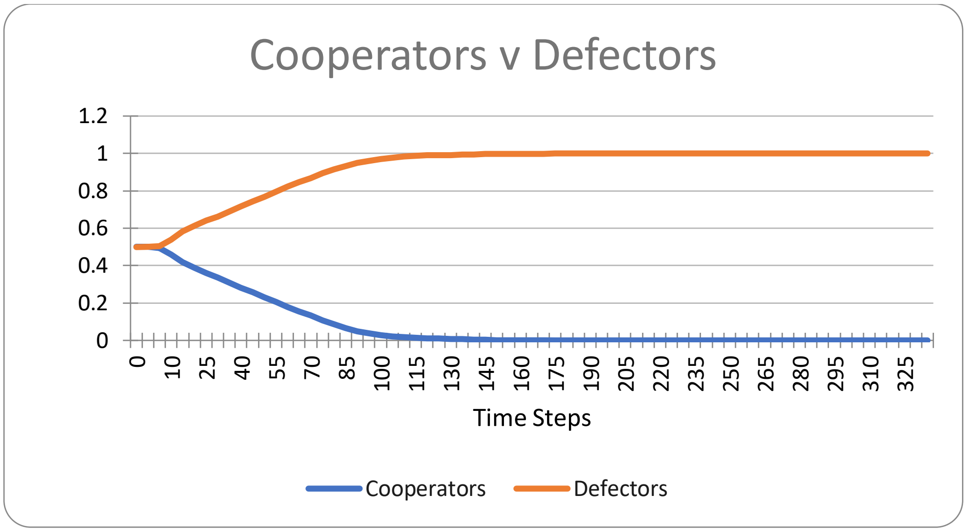


Fig 1.7

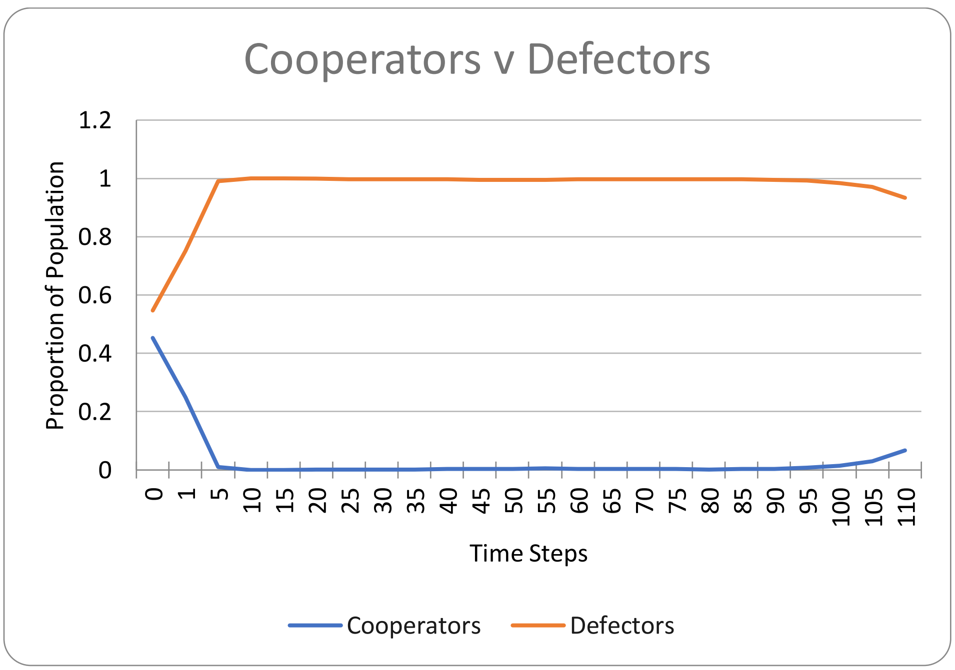


Fig 1.8

From the graphs above, we see that naïve cooperators thrive mostly when conditions are lethal (Fig 1.2, 1.4, 1.6), unless both local reproduction and groups don't exist. When conditions are nonlethal, cooperators seem to survive when only groups exist (Fig 1.1). They seem to fluctuate with defector populations when both local reproduction and groups exist, and we can see in Fig 1.3 that they defector and cooperator population are most likely to intersect once again. When only local reproduction exists, cooperators seem to survive when nonlethal, and are on an incline after a certain number of time steps (Fig 1.5). However, conditions of no local reproduction and no groups is where defectors thrive the most, under both lethal and nonlethal cases (Fig 1.7 & 1.8).

Discussion

On comparing Fig 1.1 and 1.2, we see that when LocalReproduction is set to FALSE, formation of groups only works if the consequences of trusting the wrong person are lethal. We see a similar pattern when both LocalReproduction and groups are set to TRUE as seen in Fig 1.4. Here, defectors are not entirely extinct, reason being that there is no penalty for being a mutual defector. In the case when sucker's payoff is nonlethal (Fig 1.3), cooperators and defectors seem to intersect on the graph, and then grow inversely, as defectors wander around, going from cooperator to cooperator and feeding off of them. They again seem to converge as time steps increase, however. When groups are set to TRUE and local reproduction is FALSE, we see that cooperators don't do as well when conditions are nonlethal (Fig 1.5). Although they are not thriving, cooperators seem to be surviving. Lethality favors the success of cooperators once again as shown in Fig 1.6. Over time, the defectors and cooperator population intersects, and then grows inversely, with cooperators thriving and defectors surviving. When both local reproduction and groups don't exist, defectors are the only ones thriving, and cooperators are in very low numbers for both lethal and nonlethal conditions. We can thus conclude that local reproduction might be essential for naïve cooperators. As observed, cooperators also thrive in groups and are less likely to interact with defectors then.

In general, cooperation thrives when a population is relatively static in their own large groups. Cooperators find other cooperators and repeatedly interact with their kind to avoid defectors. The converse is also true for defectors - having local reproduction guarantees that any cooperator who reproduces will have access to the offspring's resources. The offspring produced is likely to be a cooperator, and thus both agents will be able to survive for long periods of time by repeatedly cooperating with one another. Having groups could ensure relative safety and security, as multiple agents can share the same space. Nevertheless, having groups alone might not be successful – although you do share the same space, you are not guaranteed that your neighbors are going to be like you (cooperators).

Overall, we see that lethality seems to improve the success where cooperation is thriving. It can also thrive when local reproduction does not occur, which is not possible when conditions are nonlethal. We concluded that lethality tends to incentivise cooperation, when things go wrong, it becomes even more important to find your people in order to survive.

2. Experiment 2

Methods

In Experiment 2, we further analyse cooperative and defective behavior by adding a new 'walkaway' strategy to the basic strategy in the previous experiment, and we compare the behavior of walkaway cooperators versus walkaway defectors. (Walkaway cooperators default to cooperating with opponents, while walkaway defectors always default to defecting.)

For this experiment, 1000 agents (900 walkaway cooperators, 100 defectors) were placed on a 75x&5 2D grid. When they moved around and encountered another agent, each pair of agents played a round of prisoner's dilemma. The sucker's payoff, 's', was set to either -1 or -100 as in the first experiment. Additionally, defector's payoff, 'p' was introduced, and was set to -1, a minor penalty for choosing mutual defection, when s = -100. Agents were subject to 4 conditions like in the previous experiment - *(1) LocalReproduction = false, groups = true, (2) LocalReproduction = true, groups = true, (3) LocalReproduction = true, groups = false, (4) LocalReproduction = false, groups = false* with each simulation repeated 5 times.

Results

Condition 1: LocalReproduction = false, groups = true

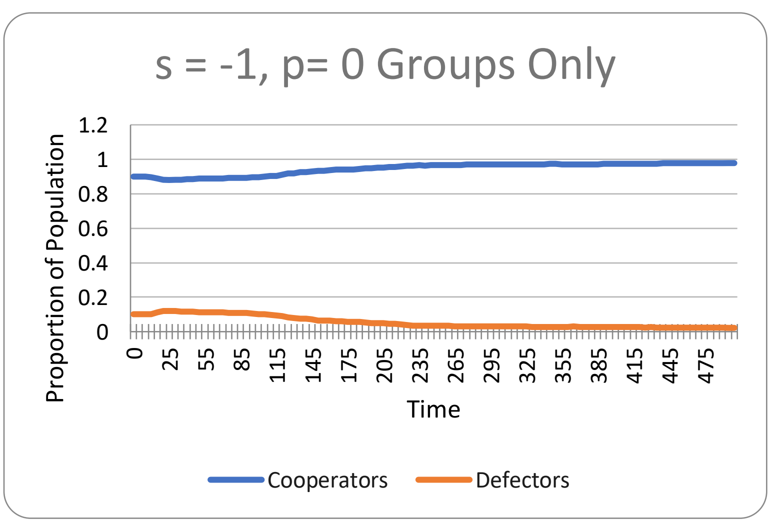


Fig 2.1

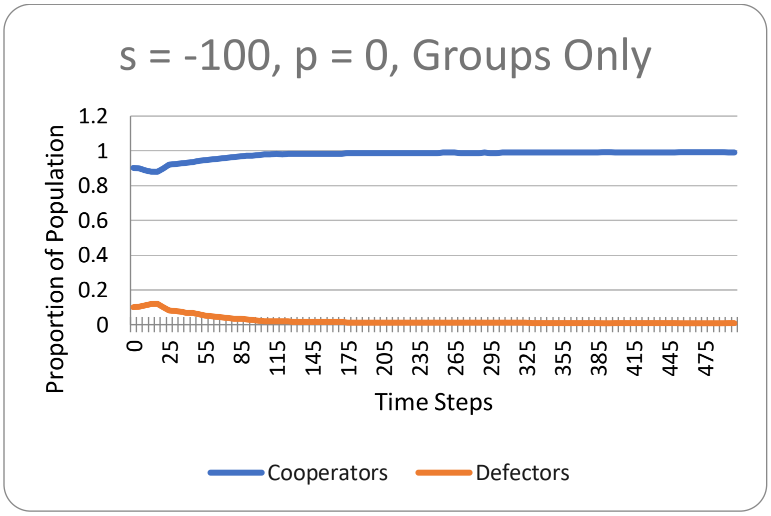


Fig 2.2

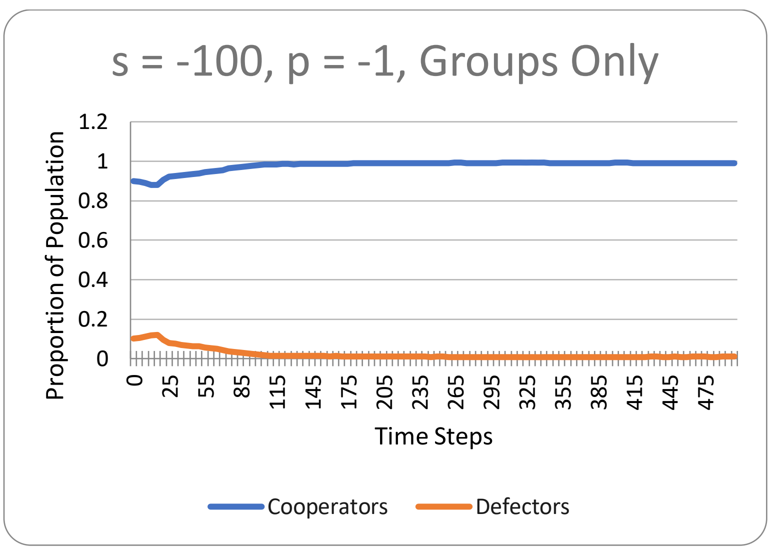
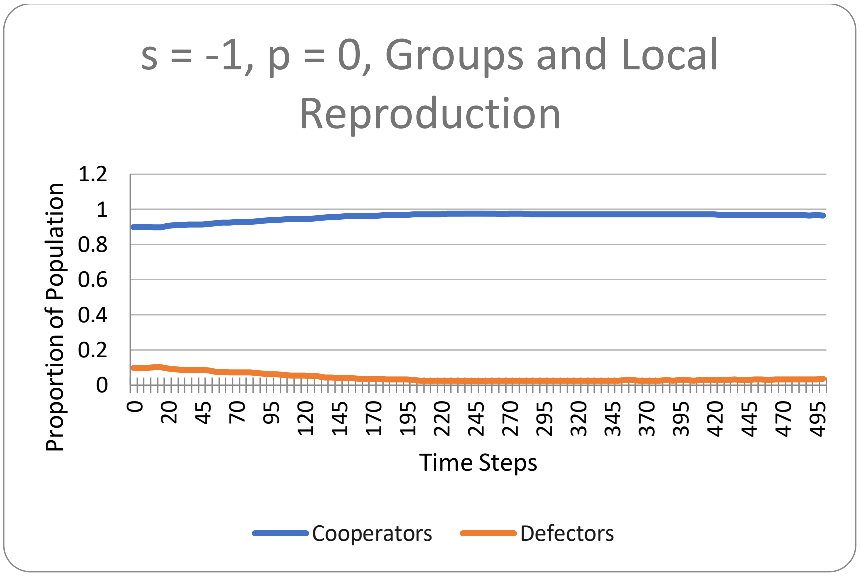


Fig 2.3

Condition 2: LocalReproduction = true, groups = true


s = -1, p = 0, Groups and Local Reproduction
Proportion of Population
1.2
1
0.8
0.6
0.4
0.2
0
0
20
45
70
95
120
145
170
195
220
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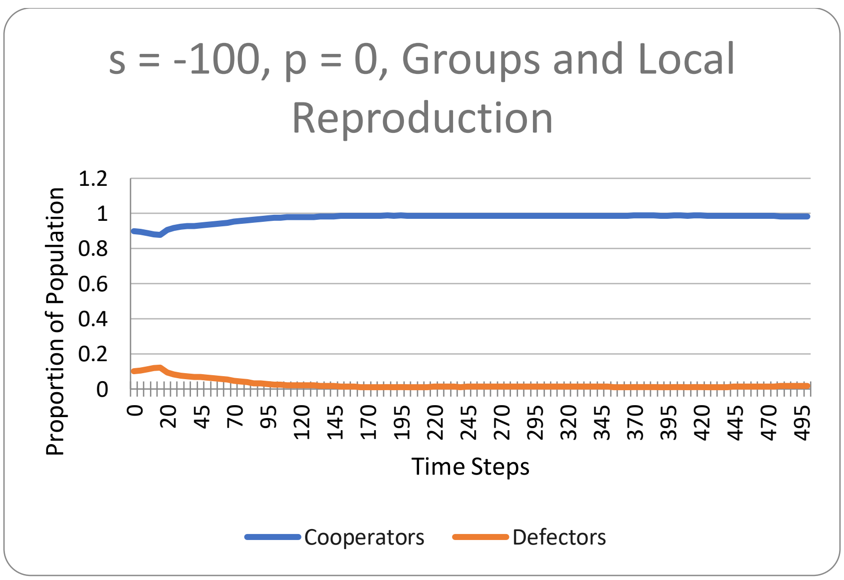
370
395
420
445
470
495
Time Steps
Cooperators
Defectors

Fig 2.4


s = -100, p = 0, Groups and Local Reproduction
Proportion of Population
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0.8
0.6
0.4
0.2
0
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45
70
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Time Steps
Cooperators
Defectors

Fig 2.5

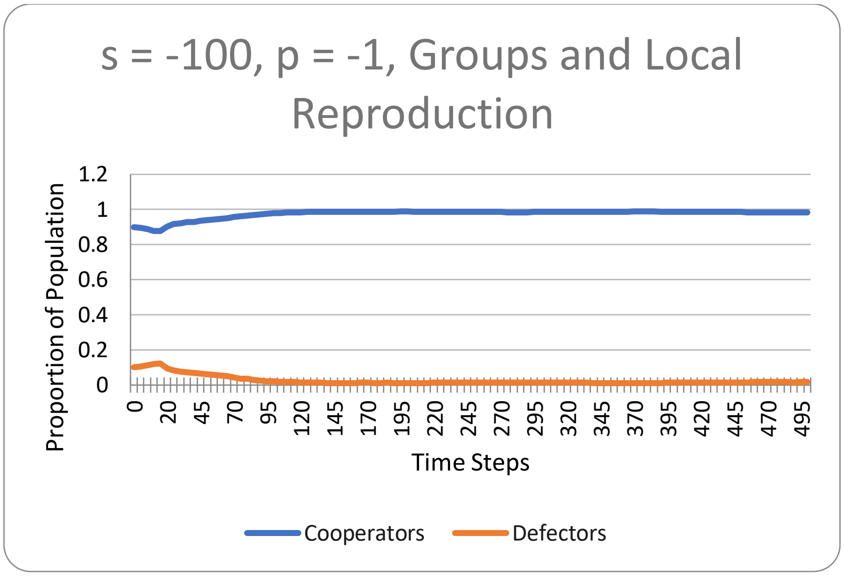


Fig 2.6

Condition 3: LocalReproduction = true, groups = false

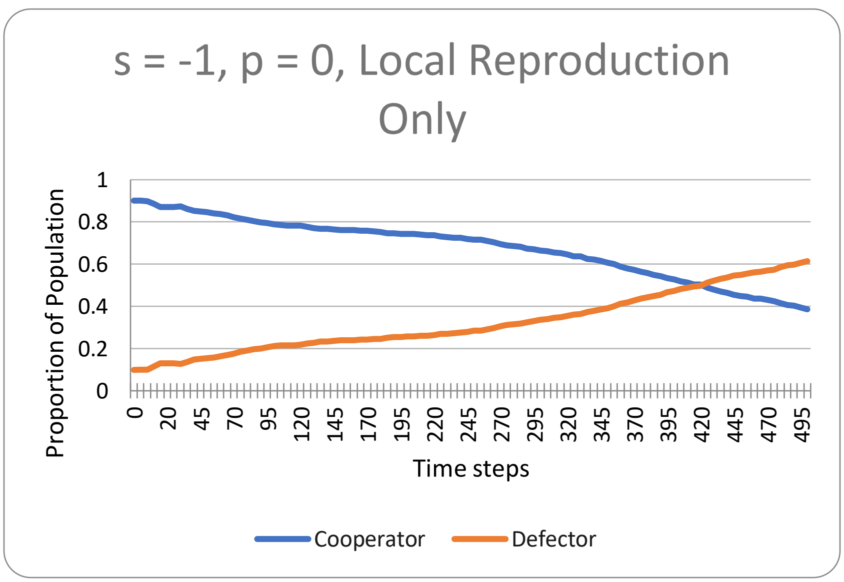


Fig 2.7

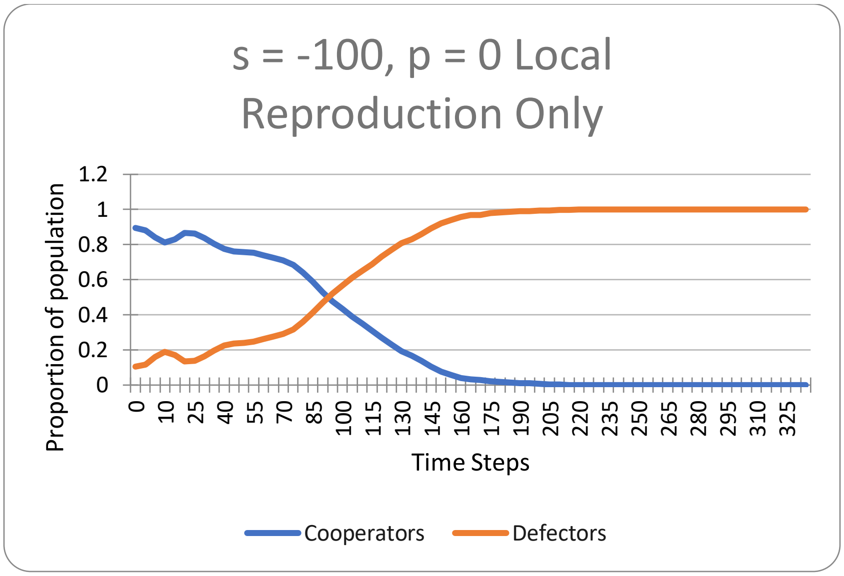


Fig 2.8

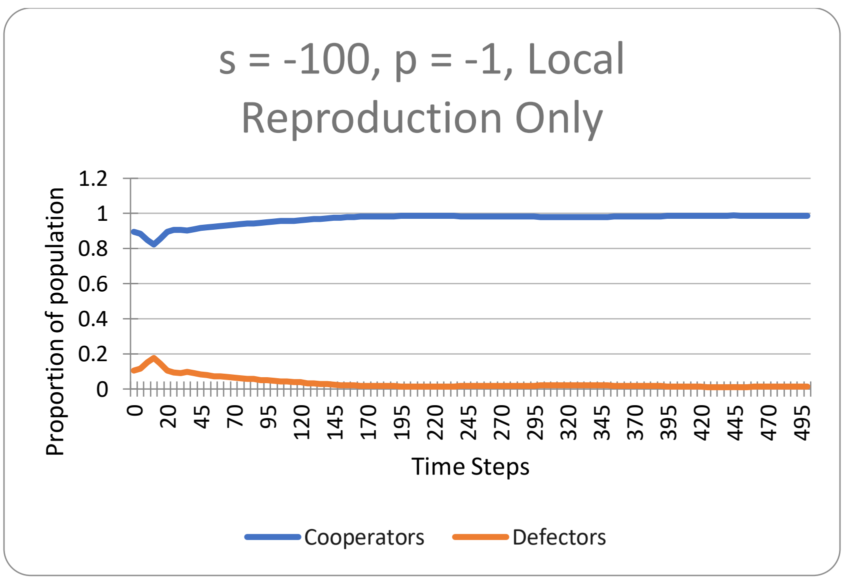


Fig 2.9

Condition 4: LocalReproduction = false, groups = false

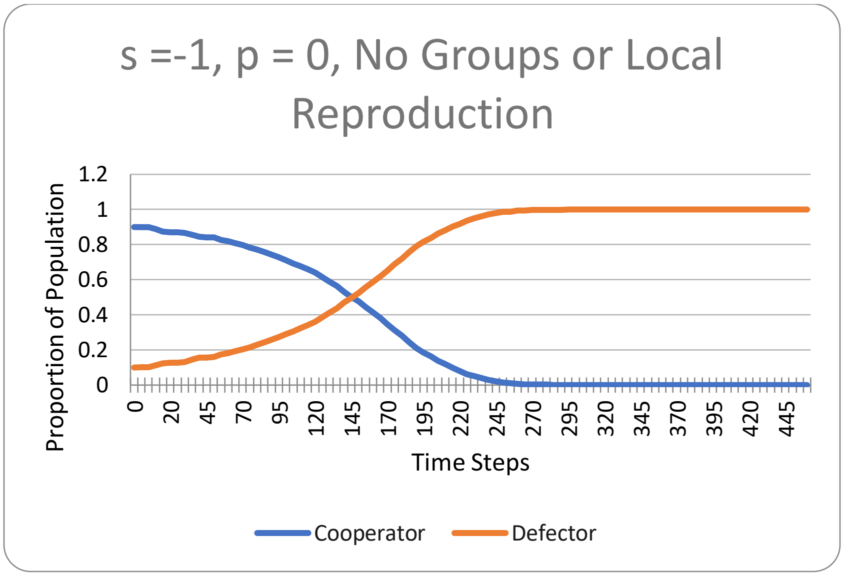


Fig 2.10

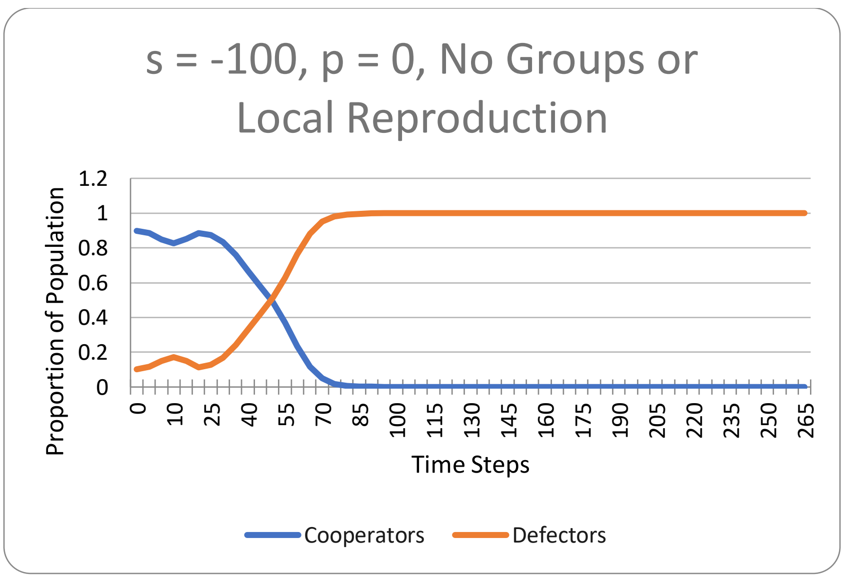


Fig 2.11

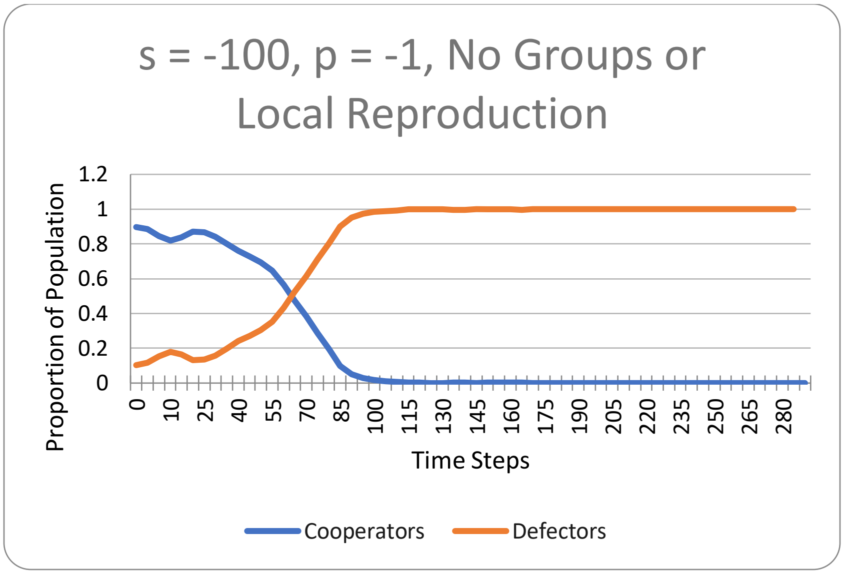


Fig 2.12

From the graphs above, we see that walkaway cooperators thrive when both groups and local reproduction variables are set to TRUE (Fig 2.4 – 2.6), or when only groups are set to TRUE (Fig 2.1 – 2.3). They also surprisingly survive under the condition when groups exist but there is no penalty for mutual defection as seen in Fig 2.1 and 2.2, which contradicts with Experiment 1, where groups helped cooperators thrive when local reproduction occurred.

This walkaway strategy helped cooperators maintain a relatively steady proportion of population as compared to the previous experiment where they would bounce back after an initial drop. When defector's payoff, 'p', was set to 0, walkaway cooperators did not do as well as defectors under conditions of just local reproduction, or no local reproduction or groups – after an initial drop, they went on a steady decline to the point of extinction. The only condition under which cooperators thrive when local reproduction is set to TRUE is when there is a penalty for mutual defection, i.e., when p = -1 (Fig 2.9).

Discussion

From the data we collected, we can see again that cooperation thrives when there is local reproduction. However, unlike Experiment 1 where cooperation and defection were naïve, the additional penalty 'p' introduced here for defectors meant that maintaining groups was essential in order for cooperation to survive.

Cooperators thrived when there were both groups and local reproduction, and the same goes when there were groups only. However, when there was only local reproduction, walkaway cooperators thrived solely when there was a penalty, i.e., when p = -1 for mutual defection. In order for cooperators to survive, agents had to be close in proximity to other cooperators and stay within their own groups. We saw that the increased mobility offered by walkaway meant that local reproduction alone was not enough to survive if a cooperator was surrounded by defectors as it would not provide agents with sufficient cooperators to pair up with and escape from defectors. While walking away to punish defectors worked to a certain extent when conditions were nonlethal, it did not when they were lethal. Defectors moved around the map and slowly eliminated cooperators without too much consequence or penalty.

Introducing the defector's payoff as another variable changes this behavior. As shown in Fig 2.9, walkaway cooperators thrive over defectors, and the only situation where this is the opposite is when p = -1, and there are no groups or local reproduction (Fig 2.12). Although a selfish strategy may benefit them in the short term, once cooperator agents run out and defectors become a majority, mutual defection seems to deteriorate them, resulting in an unstable and small proportion of the defector population. On the other hand, cooperators find each other and thrive, avoiding defectors as much as possible. Although this is a small penalty (-1) for mutual defection, we saw that it helps cooperation significantly - over time, the effect multiplies, implying that cooperation partially depends on whether or not there are long-term negative consequences of selfish, defective behavior.

3. Experiment 3

Methods

In Experiment 3, we are analysing and comparing the mobile tit-for-tat strategy (TFTM) versus Walkaway Defectors. For the TFTM strategy, agents require a memory of about 7, and thus they store the results from the 7 most recent agents they encountered, discarding memory of prior agents when space is taken up. If they have no memory of an opponent, then they cooperate by default. In this experiment, we have 1000 agents (900 TFTM, 100 Walkaway Defectors), on a 75x75 2D grid. When they move at random and encounter an opponent, they played a round of prisoner's dilemma. Similar to experiment 2, there were two sucker's payoff values, (s = -1, s = -100), and a minor defector's payoff condition (p = -1). Agents were subject to the same 4 conditions - *(1) LocalReproduction = false, groups = true, (2) LocalReproduction*

= *true*, *groups* = *true* (3) *LocalReproduction* = *true*, *groups* = *false*, (4) *LocalReproduction* = *false*, *groups* = *false*, and the simulation was run 5 times.

Results

Condition 1: LocalReproduction = false, groups = true

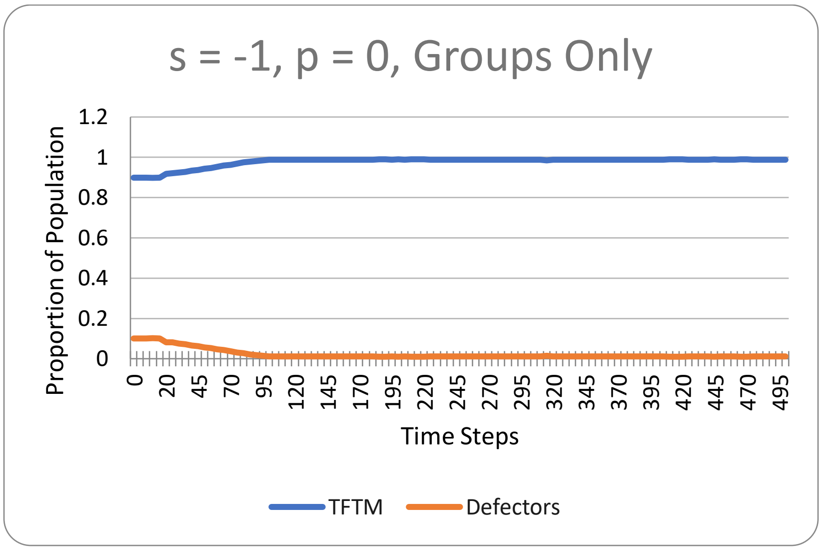


Fig 3.1

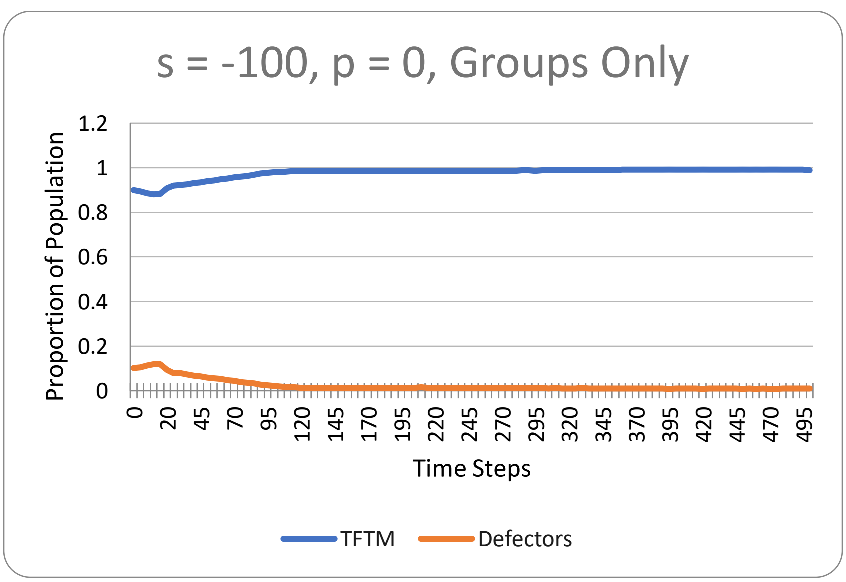


Fig 3.2

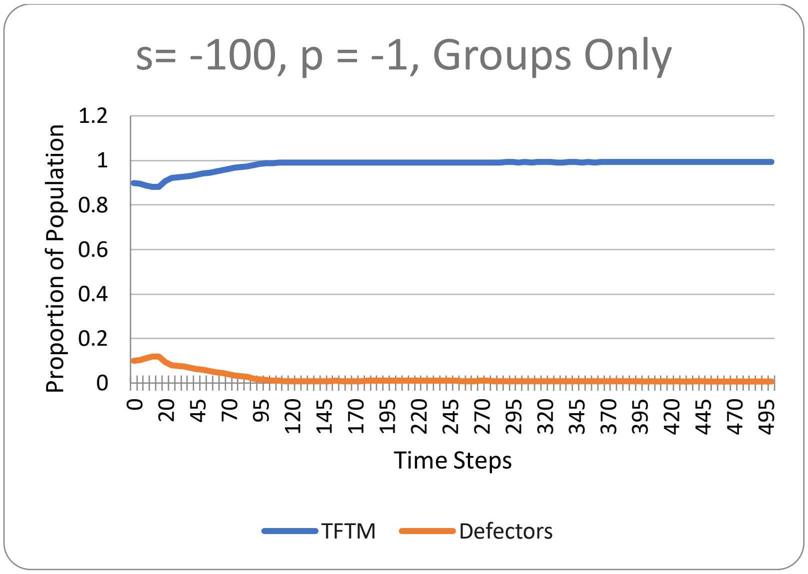


Fig 3.3

Condition 2: LocalReproduction = true, groups = true

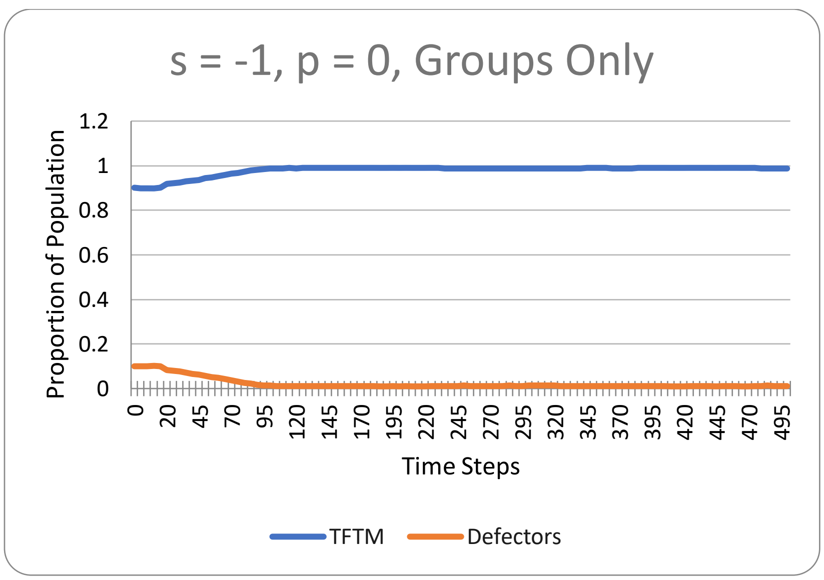


Fig 3.4

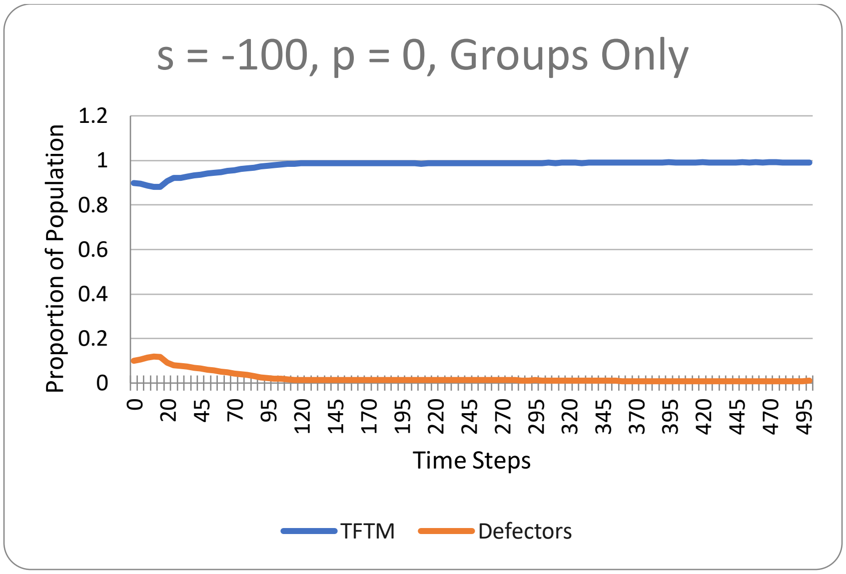


Fig 3.5

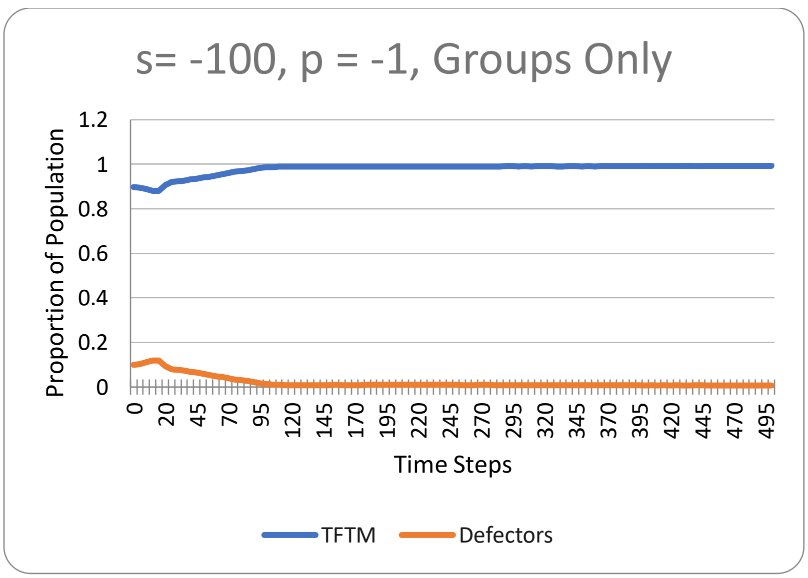
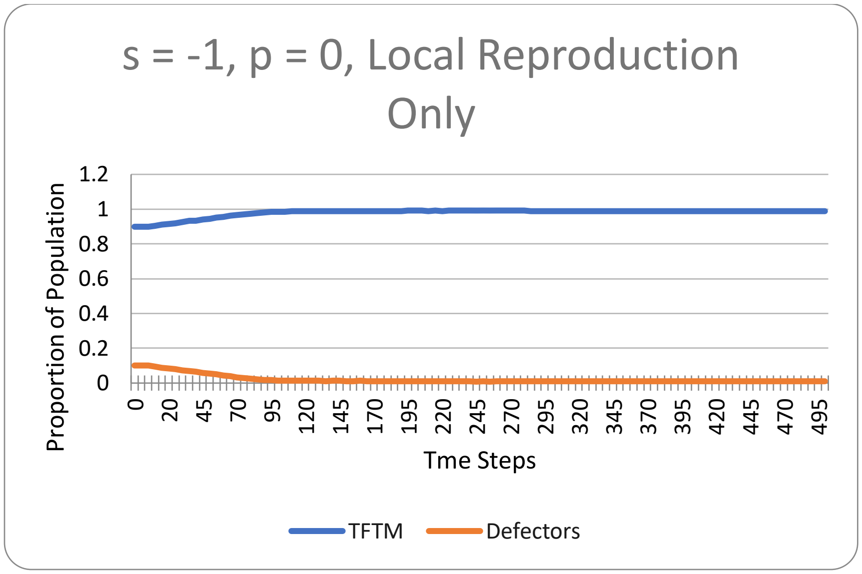


Fig 3.6

Condition 3: LocalReproduction = true, groups = false



s = -1, p = 0, Local Reproduction Only
Proportion of Population
1.2
1
0.8
0.6
0.4
0.2
0
0
20
45
70
95
120
145
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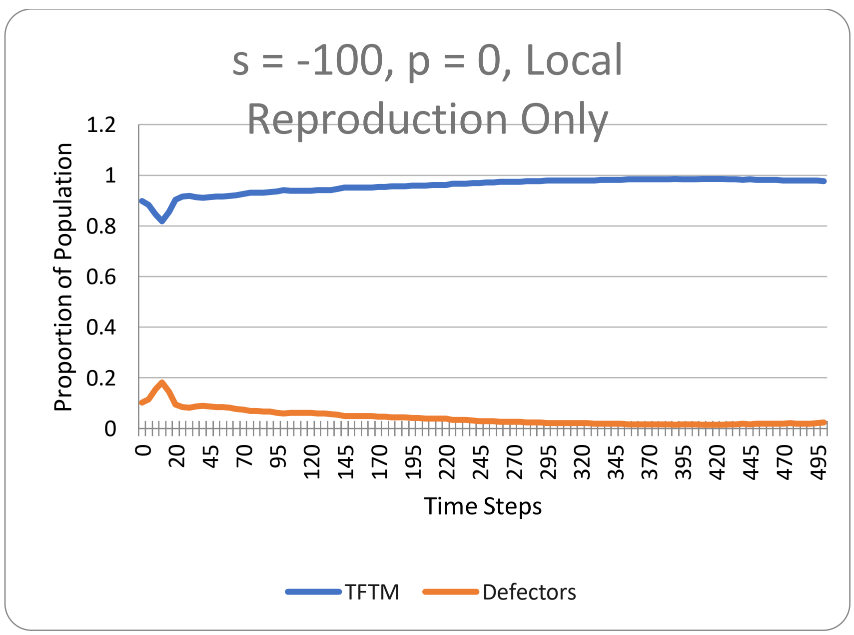
Tme Steps
TFTM
Defectors

Fig 3.7



s = -100, p = 0, Local Reproduction Only
Proportion of Population
1.2
1
0.8
0.6
0.4
0.2
0
0
20
45
70
95
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Time Steps
TFTM
Defectors

Fig 3.8

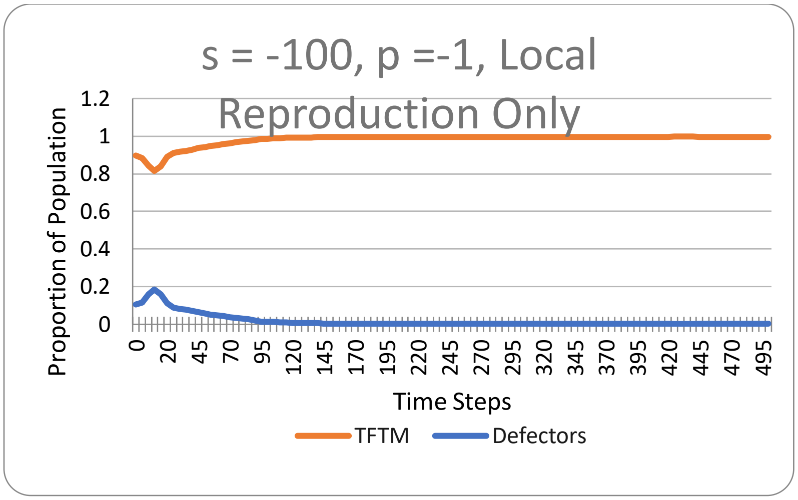


Fig 3.9

Condition 4: LocalReproduction = false, groups = false

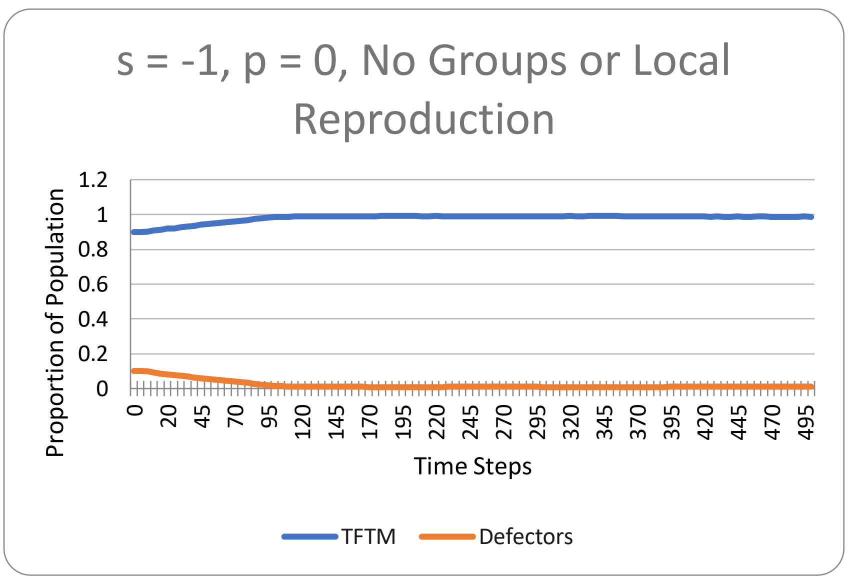


Fig 3.10

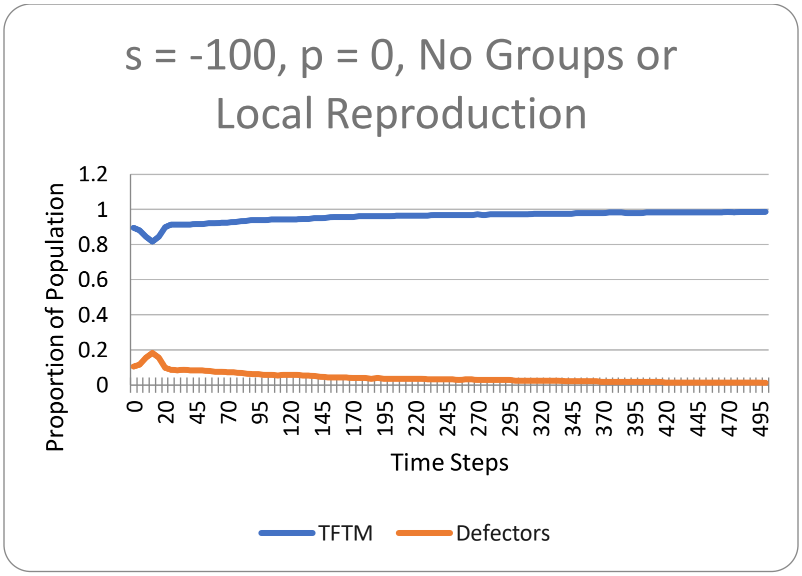


Fig 3.11

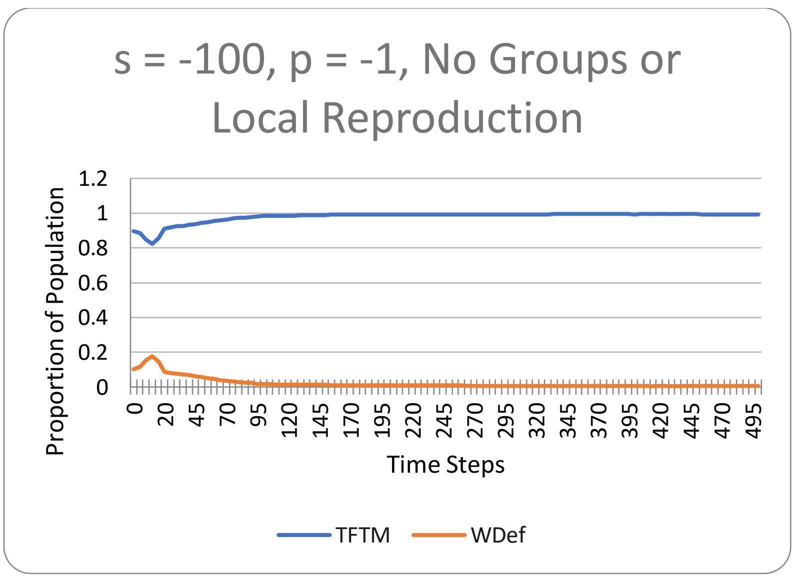


Fig 3.12

Based on the data we see in Fig 3.1-3.12 we can understand that a TFTM strategy seemed effective against a small population of walkaway defectors (100 defectors). TFTM agents thrived both when local reproduction and groups were set to TRUE and FALSE. There was a similar pattern in cases of lethal as well as nonlethal sucker's payoffs, and for the case of lethal sucker's payoffs with the additional defector's payoff (p = -1, as seen in Fig 3.3, 3.6, 3.9, 3.12).

There were minor variations in the data, nonetheless. When the sucker's payoff was set to s = -1 (Fig 3.1,3.4,3.7,3.10), we see that the TFTM agents' proportion of population increases steadily, while the walkaway defectors steadily decreased in population, to the point of close extinction. When sucker's payoff was lethal, and set to s = -100 (Fig 3.2,3.5,3.8,3.11), TFTM agents seemed to dip in population when around 16 time steps were reached and then start to increase again, while the opposite is the case for walkaway defectors – their population increased ever so slightly before decreasing back down to near-extinction. This occurred in all 4 conditions of our experiment, but was most evident when we set groups to be FALSE.

Discussion

Experiment 3 shows us that if there is a way to penalize those who exploit the system, cooperation can thrive. As we can see in Fig 3.1, 3.4, 3.7 and 3.10, TFTM agents steadily increased in the population. This could be the case because TFTM agents decide their strategy based on their previous interaction with an opponent. When surrounded by other TFTM agents, mutual cooperation takes place, as they default to cooperation if no memories have been stored. This results in a steady growth of the population.

TFTM can also work when we set groups or local reproduction to be FALSE, because it has the ability to punish cheaters, here being the walkaway defectors. Walkaway defectors quickly "walk away" after being punished on their second round of interaction with TFTM agents. We see that TFTM population increased as these agents partnered up with each other. Walkaway defector populations were always close to extinction but never became entirely extinct. This could have been because of the trivial chance that a TFTM agent produced a walkaway defector offspring.

Overall, we concluded that lethality of the sucker's payoff ('s') and defector's payoff ('p') had barely affected the overall results. The only observation we found was a dip in TFTM agents' population when time steps reach around 16, followed by a sudden increase in population (Fig 3.2, 3.5, 3.8, 3.11). This could possibly be because TFT agents ran into "murderous" defectors early on in the game, but later on found other TFT agents, leading to stable pairings as time goes on. We see this most evidently in Fig 3.11 when groups and local reproduction were both set to FALSE. The walkaway defectors, on the other hand, increased in population when groups or local reproduction was set to FALSE.

4. Experiment 4

Methods

In Experiment 4, we investigate the effect of size of memory on the results for TFT and PAVLOV strategies, two strategies that require memory for decision making. In this experiment, we have tested the tit-for-tat mobile strategy (TFTM) and pavlov mobile (PAVLOVM) strategies against a small group of walkaway defectors (WDef) at different levels of memory (1-7). We had 500 TFTM agents, 500 PAVLOVM agents, and 100 walkaway defectors. If no defectors were included in this experiment, then the entire population would stabilize, and agents would only cooperate with one another. Agents were placed on a 75x75 2D grid. Groups and local reproduction were set to TRUE, and more than one agent could occupy a given space at any given time. We set the sucker's payoff 's' to -100 for lethal conditions and -10 for nonlethal conditions, in order to see what happens when TFTM and PAVLOVM agents are not killed by defectors in the first round. We additionally set defector's payoff 'p' to be -1.

Results

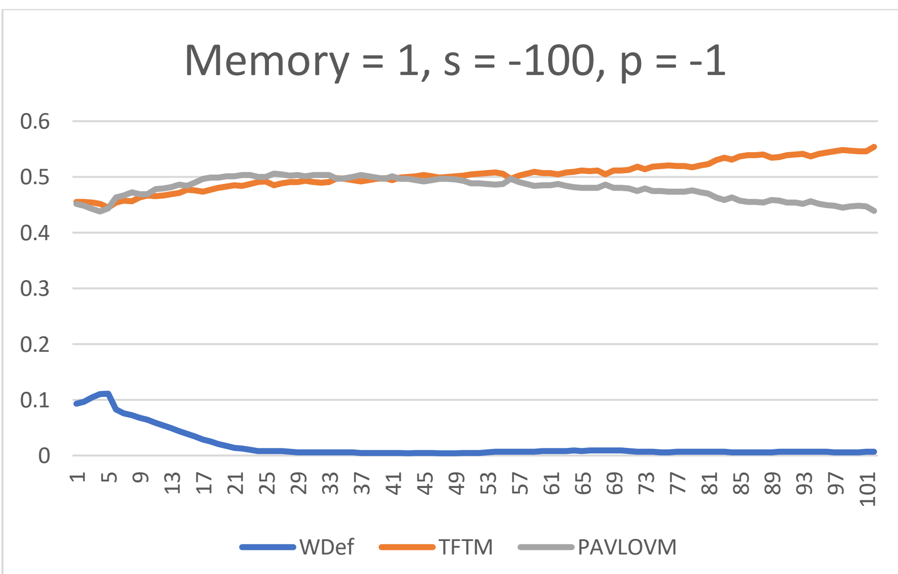
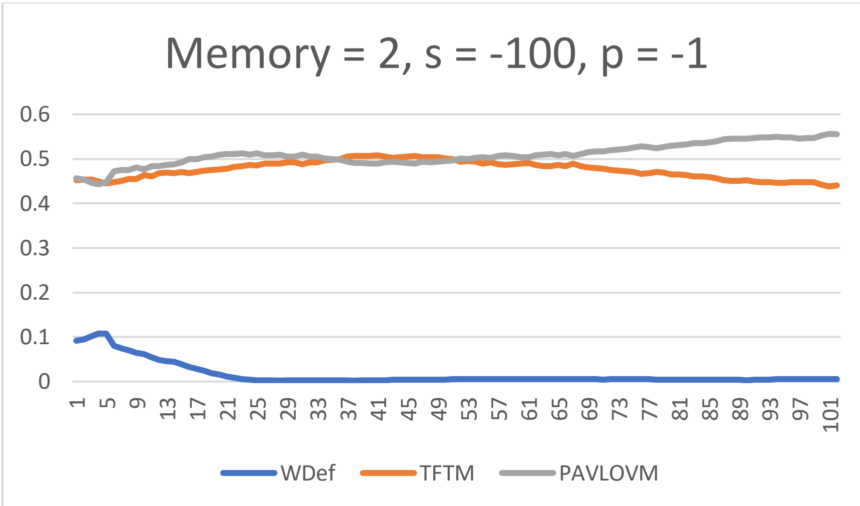
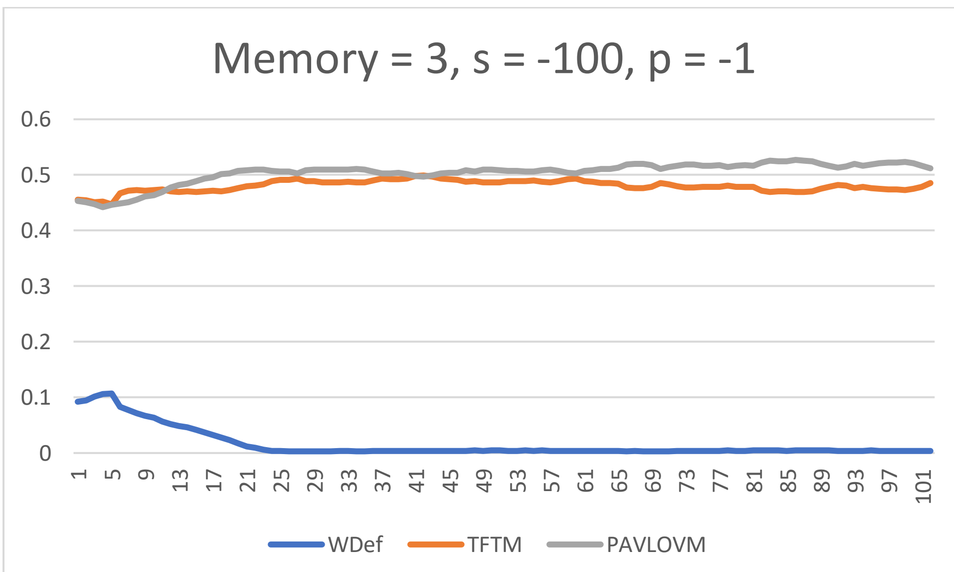


Fig 4.1



Memory = 2, s = -100, p = -1
0.6
0.5
0.4
0.3
0.2
0.1
0
1
5
9
13
17
21
25
29
33
37
41
45
49
53
57
61
65
69
73
77
81
85
89
93
97
101
WDef
TFTM
PAVLOVM

Fig 4.2



Memory = 3, s = -100, p = -1
0.6
0.5
0.4
0.3
0.2
0.1
0
1
5
9
13
17
21
25
29
33
37
41
45
49
53
57
61
65
69
73
77
81
85
89
93
97
101
WDef
TFTM
PAVLOVM

Fig 4.3

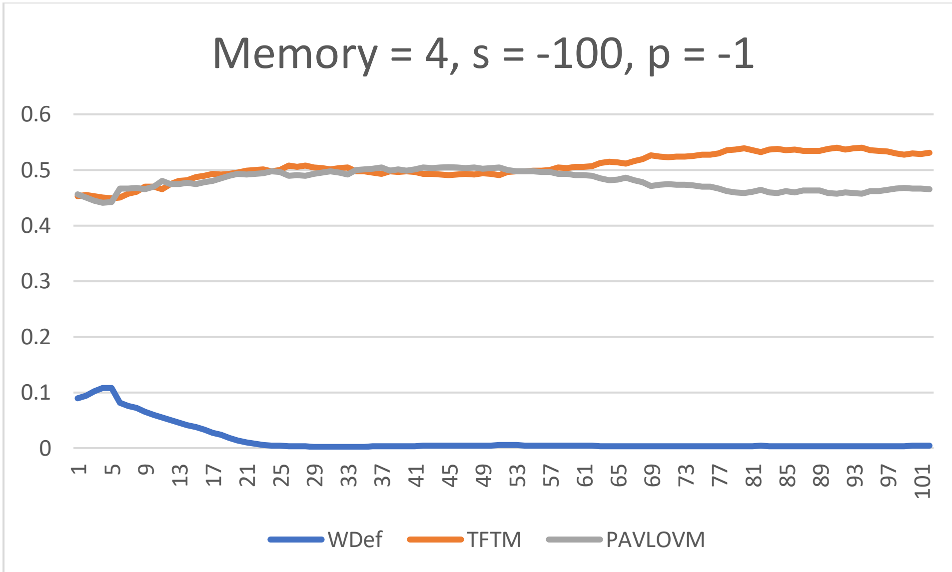

Memory = 4, s = -100, p = -1
0.6
0.5
0.4
0.3
0.2
0.1
0
1
5
9
13
17
21
25
29
33
37
41
45
49
53
57
61
65
69
73
77
81
85
89
93
97
101
WDef
TFTM
PAVLOVM

Fig 4.4

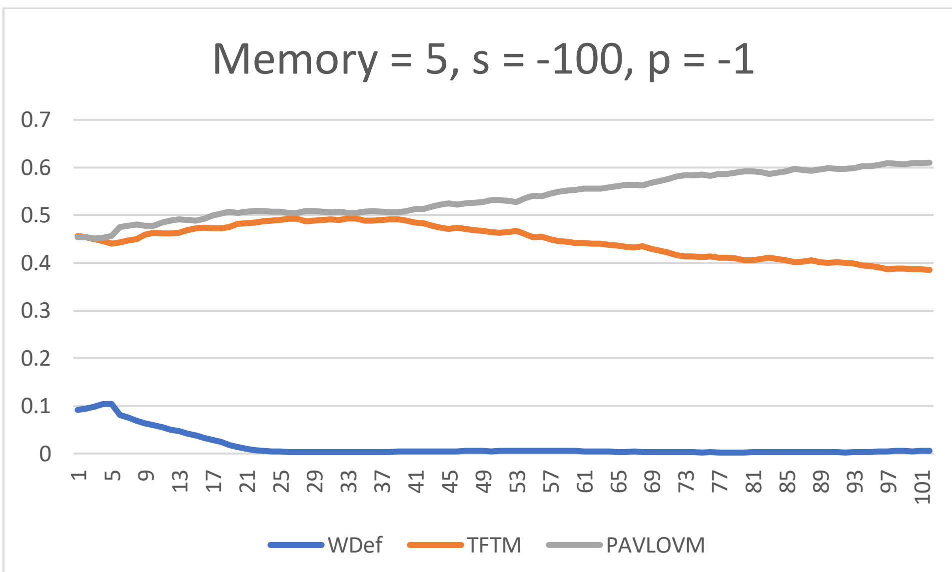
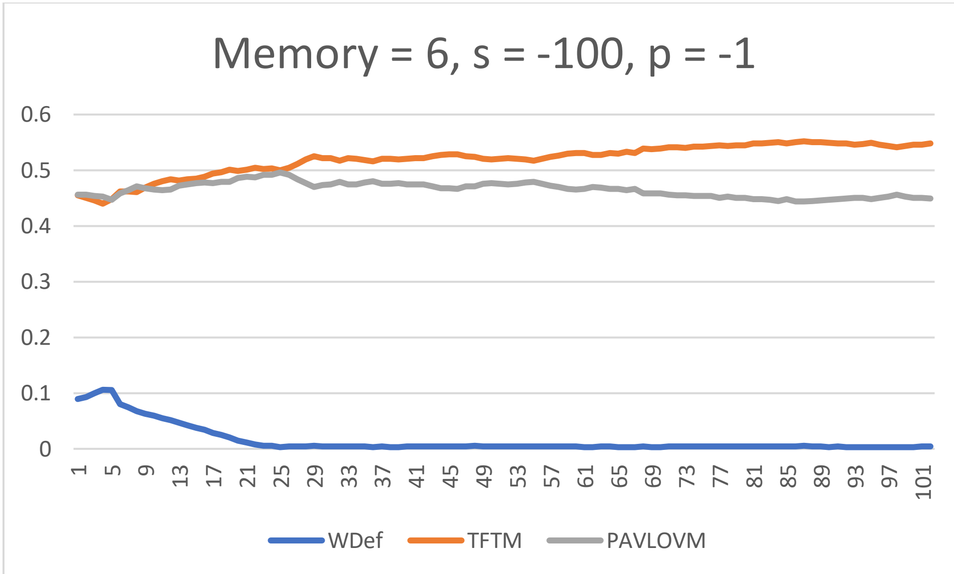
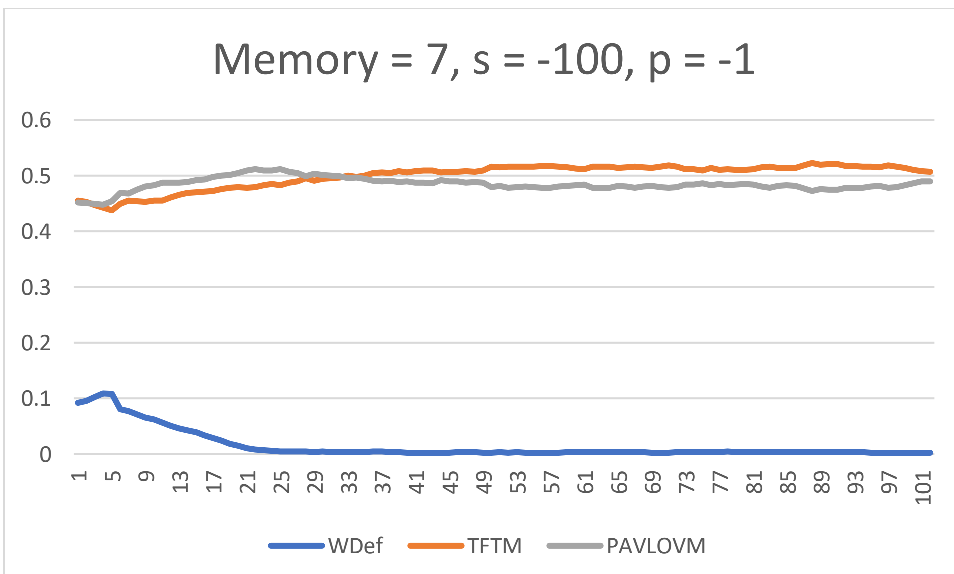

Memory = 5, s = -100, p = -1
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
5
9
13
17
21
25
29
33
37
41
45
49
53
57
61
65
69
73
77
81
85
89
93
97
101
WDef
TFTM
PAVLOVM

Fig 4.5



Memory = 6, s = -100, p = -1
0.6
0.5
0.4
0.3
0.2
0.1
0
1
5
9
13
17
21
25
29
33
37
41
45
49
53
57
61
65
69
73
77
81
85
89
93
97
101
WDef
TFTM
PAVLOVM

Fig 4.6



Memory = 7, s = -100, p = -1
0.6
0.5
0.4
0.3
0.2
0.1
0
1
5
9
13
17
21
25
29
33
37
41
45
49
53
57
61
65
69
73
77
81
85
89
93
97
101
WDef
TFTM
PAVLOVM

Fig 4.7

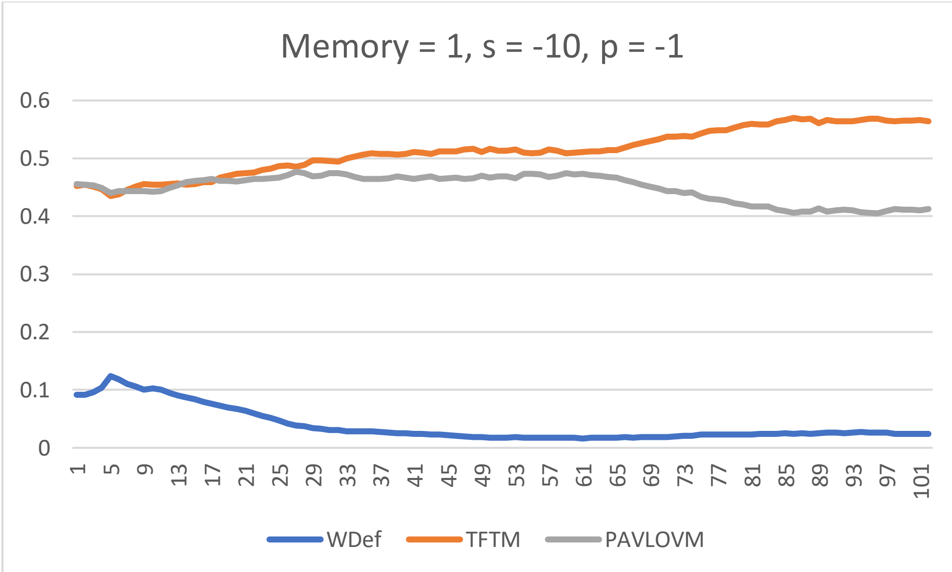

Memory = 1, s = -10, p = -1
0.6
0.5
0.4
0.3
0.2
0.1
0
1 5 9 13 17 21 25 29 33 37 41 45 49 53 57 61 65 69 73 77 81 85 89 93 97 101
WDef
TFTM
PAVLOVM

Fig 4.8

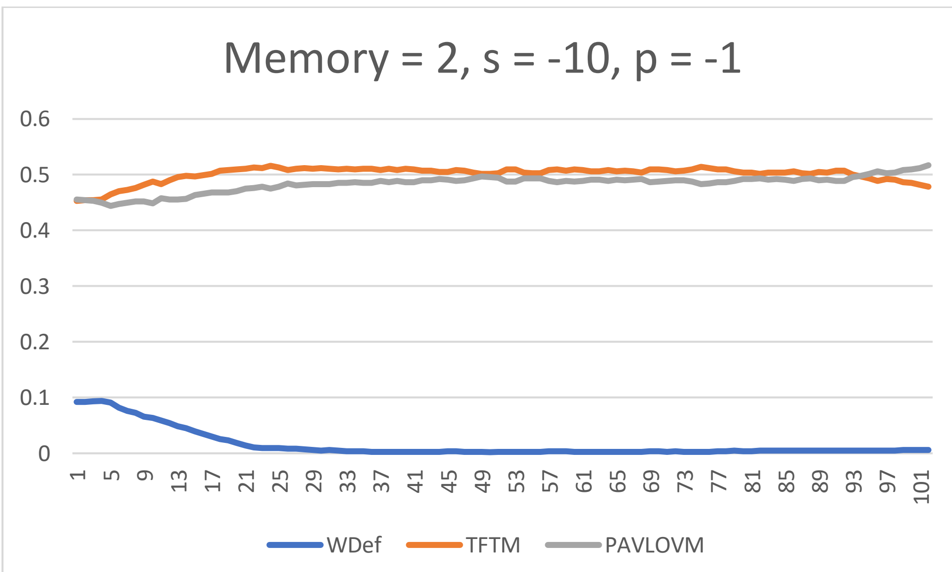

Memory = 2, s = -10, p = -1
0.6
0.5
0.4
0.3
0.2
0.1
0
1 5 9 13 17 21 25 29 33 37 41 45 49 53 57 61 65 69 73 77 81 85 89 93 97 101
WDef
TFTM
PAVLOVM

Fig 4.9

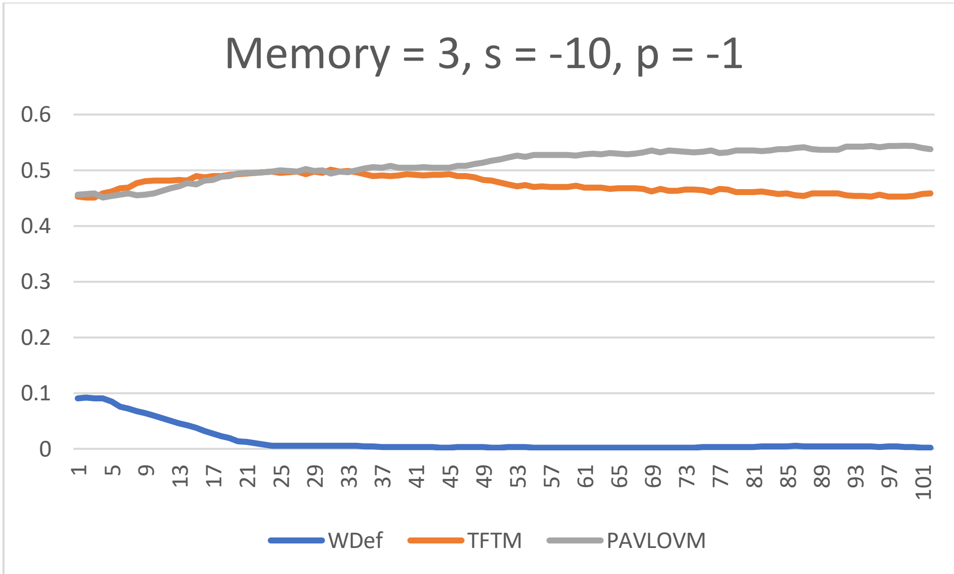


Fig 4.10

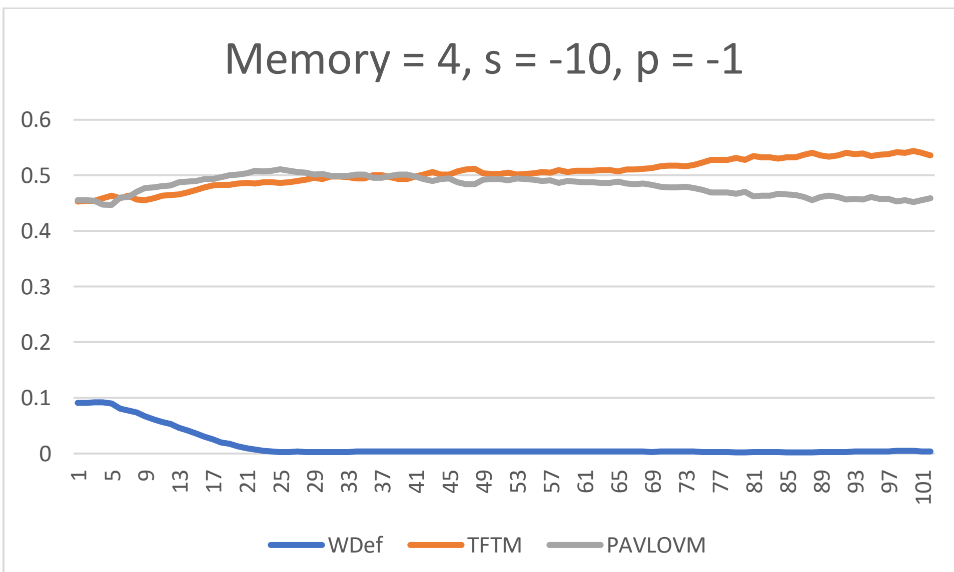


Fig 4.11

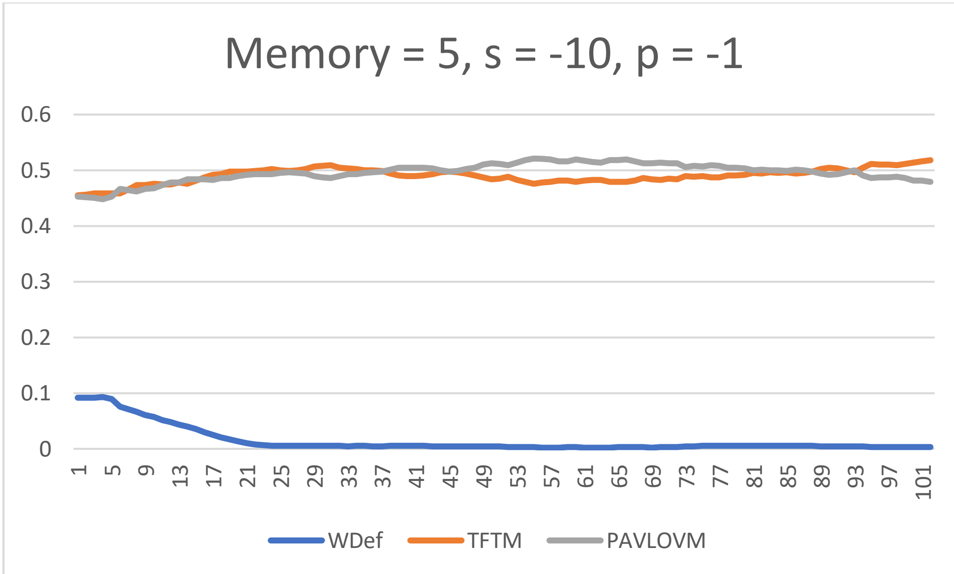


Fig 4.12

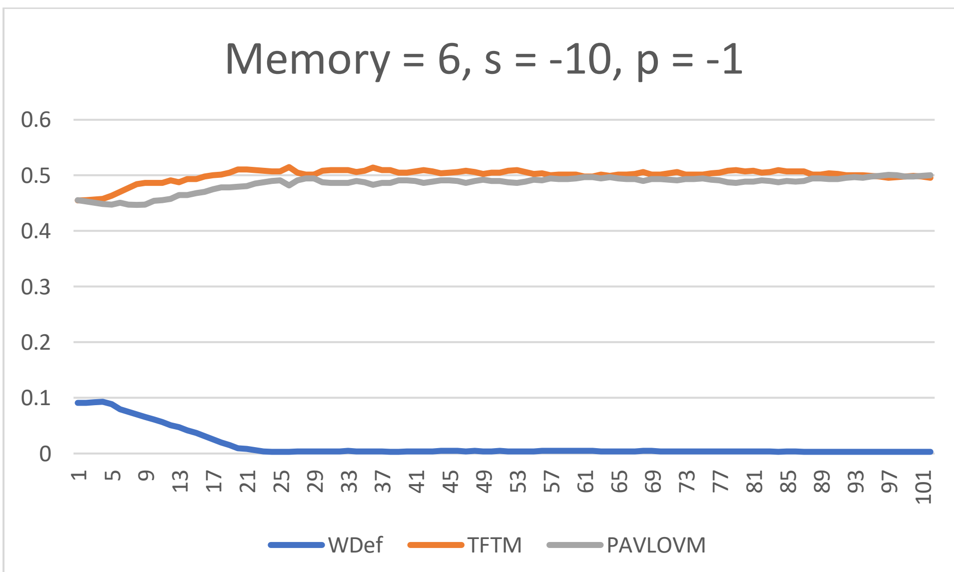


Fig 4.13

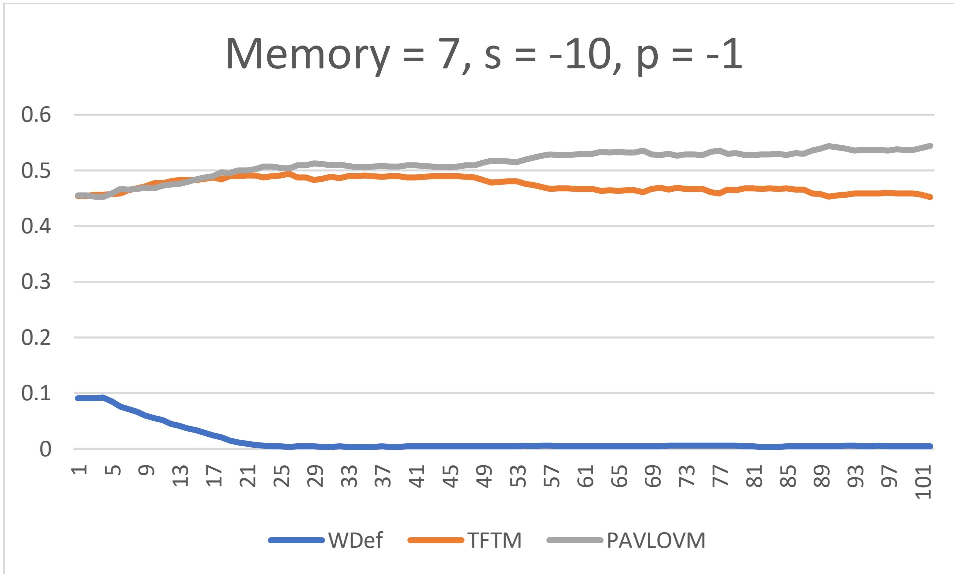


Fig 4.14

The results from experiment 4 indicate that although both TFTM and PAVLOVM depend on memory, the overall success of these strategies stayed stable (as seen in Fig 4.1 – 4.14). At lower memory capacity, however, the success rates tend to fluctuate differently for both TFT and PAVLOV.

In general, TFTM and PAVLOVM strategies held off the small defector population relatively well. As shown in Figure 4.1, when sucker's payoff was detrimental but not lethal, the defectors only experienced small temporary gains in populations until they dropped back down to close extinction eventually. In all of the other nonlethal sucker's payoff conditions (Fig 4.2-4.7), walkaway defectors populations remained stable before steadily decreasing until the end. The lethal sucker's payoff conditions gave slightly different results - as shown in Fig 4.8-4.14, the walkaway defectors always had minor gains in population before steadily dropping back down to near-extinction.

We tried to replicate the ideal environment for cooperative behavior to thrive as seen in Experiment 1, as well as incorporating certain factors from Experiment 2 and 3. Overall, however, it is challenging to conclude which strategy worked significantly better.

Discussion

Based on our results of Experiment 4, we see that memory may not be as significant or important in the overall survival of populations, though it may impact the survival of individuals.

When groups and local reproduction were set to TRUE, TFTM or PAVLOVM agents could have possibly interacted or been in close proximity to a defector population in the early time steps. Having little memory (suppose memory = 1), they cooperated with defectors they had forgotten, resulting in the slight increase in defector populations as we see in Fig 4.1. TFTM agents could cooperate with a walkaway defector on the 1st round, and defect on the 2nd round of the nonlethal sucker's payoff condition (s = -10). The walkaway defector would then walk away. If these TFTM agents repeated the process with a different defector, and if memory = 1, TFTM agents could only remember what the immediate prior agent did. Thus, the initial defector could take advantage of the TFTM agent multiple times when we set s = -10 and p = -1.

PAVLOVM agents, on the other had would not have remembered to switch strategies when they lost, which we assumed affects them long-term. However, Fig 4.1 shows the opposite – here, we see the population proportions increasing. We concluded that this could be because most of the TFTM agents and PAVLOVM agents found other TFTM and PAVLOVM agents who would not default to defection, and thus allowing the population to form stable groups that continued to cooperate with each other.

As memory increases, we see that it brings down defector populations (Fig 4.8 – 4.14) in the nonlethal conditions (s = -10). TFTM and PAVLOVM agents were less likely to decline, as they could remember to switch their initial strategy and beat defectors. In lethal conditions, when s = -100, defector agents made small gains in the beginning, but almost completely became extinct later on. We realised that this could be because TFTM and PAVLOVM agents were in close proximity to one another. These agents had no memory, resulting in their cooperation with the defector. Sucker's payoff was also lethal; thus, they were gotten rid of after the first chance. The results from Fig 4.1 - 4.7 show a small gain in defector populations, whereas PAVLOVM and TFTM populations drop for all memory sizes. PAVLOVM and TFTM agents eventually formed stable groups, however, while defector populations declined due to mutual defection.

We can conclude that agents tend to boost the overall survival of cooperation at least in environments that encourage cooperation. Through this experiment, we can see that memory does not seem to play a huge role in the survival of a large population overall. Memory increases the survival of individuals to some extent, however, when there is leverage to trust the wrong individuals.

5. General Discussion

The four experiments conducted show us how changing up environmental conditions around agents can affect the survival of cooperation. We were able to find specific conditions that led to the emergence and survival of cooperation long term as well.

In Experiment 1, we saw that cooperation in general depended on local reproduction in order to have a set of individuals to cooperate with and depend on for survival. The presence of groups can enable this by allowing individuals to easily find other individuals to depend on. However, these individuals are not guaranteed to be like them, unless we introduce a lethal sucker's payoff. Although both groups and local reproduction play a significant role in cooperation, they do not contribute equally.

The results of Experiment 2 support our previous experiment. In this experiment, local reproduction was not enough to maintain the population of cooperators, unless there was a penalty or punishment for mutual defection. We found that the presence of groups alone helped cooperators survive and thrive, however. Local reproduction alone was enough only when there was a defector's payoff ($p = -1$), since defectors eventually produced defector offspring with cooperators that they previously interacted with, and these offspring would turn hostile to their parent defectors.

In Experiment 3, we see that cooperation can thrive if exploiters of the system are penalized. Tit-for-tat mobile (TFTM) agents steadily increased in the population, since their strategy was based on their previous interaction with an opponent. When surrounded by other like agents, mutual cooperation takes place, resulting in a steady growth of the population. We see that TFTM works even in the absence of groups or local reproduction, due to the punishment given to cheaters, thus resulting in the decline of defectors. We observed that the lethality of the sucker's payoff and defector's payoff had barely affected the overall results.

Experiment 4 helped us understand if memory is important for cooperation. We found that although it does not help the overall survival of populations, it may impact the survival of individuals. We concluded that memory would be the most beneficial if the population was more balanced, or for populations that were a minority, which can be something to be looked at in future studies.

Something that we found interesting through running these experiments was when we compared PAVLOVM and TFTM. When it came to which worked better, theoretically, TFTM is a lot more direct and thus would work significantly better, but when we ran our model, it lost against PAVLOV in some cases in Experiment 3. The theoretical predictions did not match what actually happened through our experiment. Thus, it is essential to keep in mind that although experiments and models such as this can help us understand human behavior better, it is not an accurate model of what happens in the real world. This finding opened my eyes to the fact that people change and grow all the time, and behaviors are not necessarily consistent. It is not possible for a model to precisely capture and predict cooperation or defection, and this is the beauty of how complex human behavior can be!