Introduction

To study evolutionary game theory and the different strategies that can be employed an Agent Based Model has been created to simulate real world interactions. Agents with set strategies are placed into a 2D grid where they can move around each turn to attempt to interact with other agents inside a set radius. When agents meet they play a game of the Prisoner's Dilemma where each agent decides whether to cooperate or defect. Each agent has an energy number which if it gets too low will cause the agent to die and if it gets high enough that agent will reproduce. Based on what each agent decides to do during the Prisoner's Dilemma game, the agent will either add to their energy or subtract from it. The different strategies that can be used start simple with the naive cooperator and naive defector. These agents will either cooperate every time in the case of the naive cooperate or defect every time in the case of the naive defector. Two other strategies are the walkaway defector and walkaway cooperator which add a level of complexity. These agents will either cooperate or defect every time depending on which strategy and if their partner defects then they will move away in an attempt to find a different partner. The most complex strategies are the TFT and PAVLOV strategies which both have mobile and stationary versions. The mobile versions move until they find a partner, while the stationary versions never move. These strategies have memories that are set to a certain size to remember what agents that they interacted with before have chosen to do when they meet. TFT agents will always cooperate with agents that have cooperated with them and defect against agents that have defected against them. PAVLOV agents will always stay with whatever strategy they previously used if the other agent cooperates and they will change strategies if the other agent defects. The goal of these simulations are to gain a better understanding of the conditions that each strategy succeeds or fails in.

Topic #1: Cooperators vs. Walkaway Defectors

Intro:

The first question that was explored was how would things change when walkaway defectors were added into the simulation against cooperators. This simulated a scenario where the walkaway defectors would prey on cooperators and continue to attempt to take advantage of them to survive and thrive. The cooperators would not learn to defend against these walkaway defectors so the simulation would show if both the populations of cooperators and walkaway defectors could survive when there was one group of agents that would constantly be taken advantage of. Different levels of the sucker's payoff were tested. Looking at this simulation naively it would seem that if the sucker's payoff was more negative, then the cooperators would struggle to survive against the walkaway defectors.

Methods:

To run this simulation there were 500 agents each of cooperators and walkaway defectors to begin with. The parameters that were tested were mutations, groups, and the sucker's payoff. The first 8 simulations began with mutationRate = 0. These were run with groups enabled and disabled with the sucker's payoff ranging from 0 to -2.0 at increments of 0.5. The mutationRate was then changed to 0.01 and the same parameters were tested with enabled and disabled with the sucker's payoff ranging from 0 to -2.0 at increments of 0.5.

Results:

In most scenarios when there were no mutations the cooperators would dominate the simulation. The only case in which this did not happen is when the sucker's payoff was 0. When the sucker's payoff was 0 and groups were enabled the cooperators and walkaway defectors were about even in numbers by the end of the simulation which can be seen in Figure 1.1. With groups disabled and the sucker's payoff at 0 about 1% of the final population was walkaway defectors with the rest being cooperators as seen in Figure 1.2. When mutations were added to the simulation the results changed drastically. With groups enabled the walkaway defectors dominated with all sucker's payoff amounts except for 0.0. When the sucker's payoff was 0.0 the walkaway defectors were still a majority, but the cooperators were close. With groups disabled the walkaway completely dominated all scenarios except when the sucker's payoff was 0. With the sucker's payoff at 0 the cooperators were a majority of the population, but the walkaway defectors started out strong and ended at around 45% of the population.

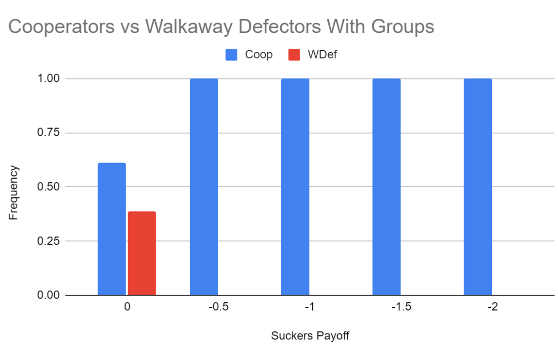
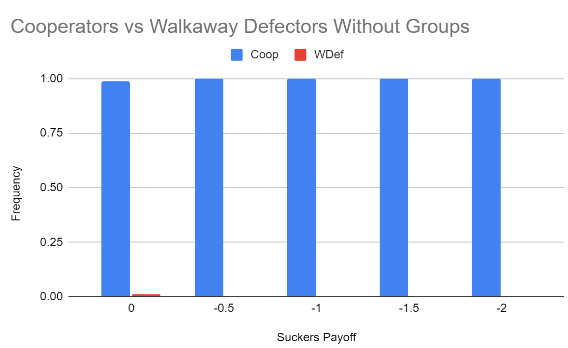


Figure 1.1



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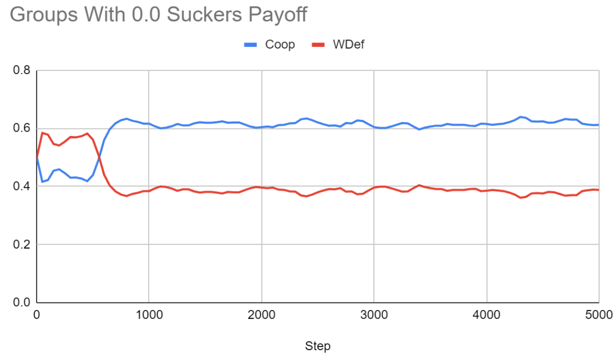

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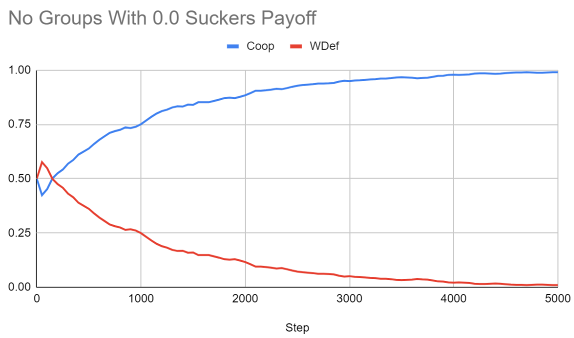

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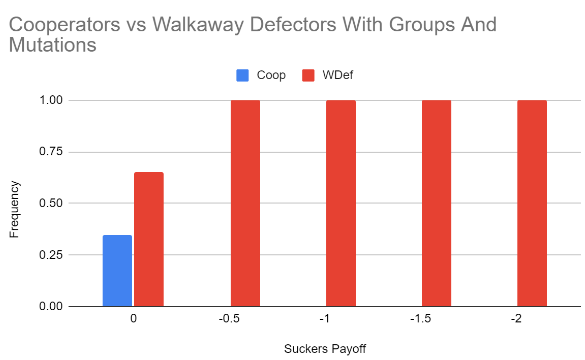

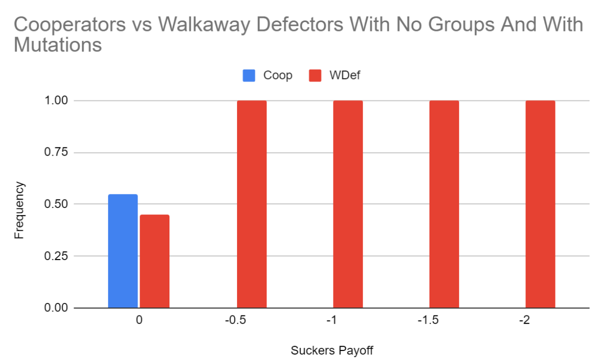

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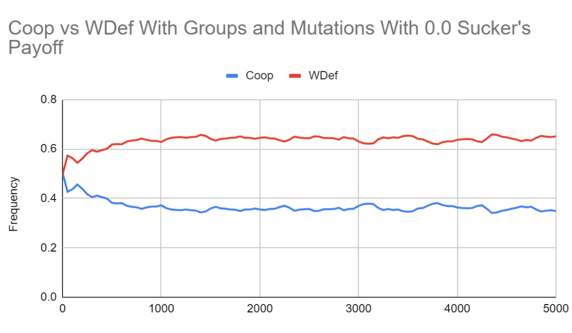


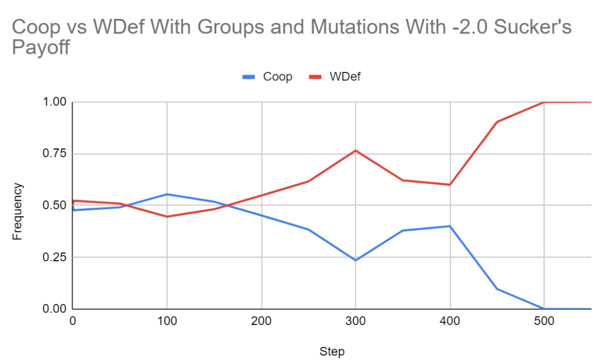
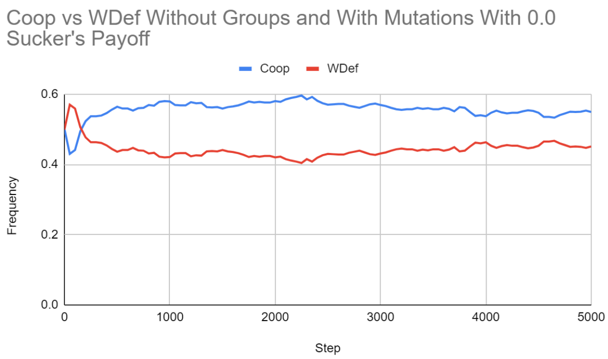


Figure 1.9 **Figure 1.11**



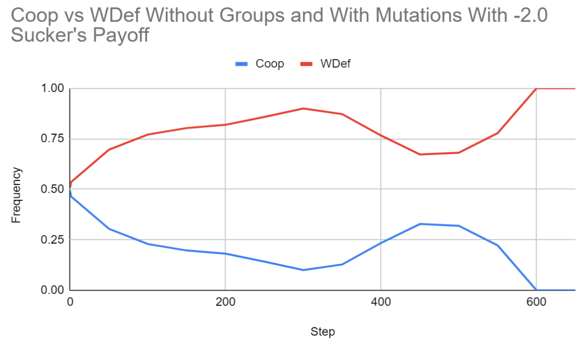


Figure 1.12 **Figure 1.13**

Discussion:

Despite the initial thought that the walkaway defectors would wipe out the cooperators, when there were not mutations it was actually the other way around. In almost all of these cases the cooperators ended the simulation as 100% or close to 100% of the population. The explanation for this could be that the cooperators that interacted with other cooperators thrived, while the walkaway defectors that interacted with cooperators would kill off the cooperators and then have to go find another cooperator or else they would die off. When the sucker's payoff was 0 and groups were enabled the walkaway defector could take advantage of cooperators without the cooperators taking a negative penalty. The cooperators could survive interacting with both other cooperators and walkaway defectors. When mutations were added the cooperators could still survive when the sucker's payoff was 0, but when the cooperators would have a penalty for interacting with walkaway defectors the walkaway defectors did much better and the cooperators were killed off because the walkaway defectors would continue to be created through mutations.

Topic #2: Walkaway Cooperators vs. Walkaway Defectors

Intro:

After testing how walkaway defectors would do against naive cooperators, the next step was to test how the walkaway defectors would do against walkaway cooperators. The thinking was that in the walkaway cooperators would not be as prone to being exploited by the walkaway defectors as the naive cooperators were in certain situations. This is because the naive cooperators would not move away when the walkaway defectors were defecting against them, but the walkaway cooperators would move if they interacted with the walkaway defector.

Methods:

To test this scenario, 500 walkaway defectors were placed with 500 walkaway cooperators. The parameters that were changed were the same as the previous scenario. All scenarios were tested with both mutation rate at 0 and mutation rate at

0.01. The scenario was tested with both groups enabled and groups disabled and with differing sucker's payoff amounts. The sucker's payoff was tested between values of 0 - -2.0 at increments of 0.5.

Results:

Without any mutations the walkaway cooperators dominated the walkaway defectors. The walkaway defectors were completely wiped out in all scenarios except for when groups were disabled and the sucker's payoff was set to 0 which can be seen in Figure 2.1 and Figure 2.2. When groups were enabled the walkaway cooperators wiped the walkaway defectors out extremely quickly, but with groups disabled it took longer for this to happen which can be seen in Figures 2.3-2.6. When the mutation rate was set to 0.01 the results completely flipped with the walkaway defectors completely dominating and only a small number of walkaway cooperators surviving when the sucker's payoff was set to 0 which can be seen in Figures 2.7-2.8.

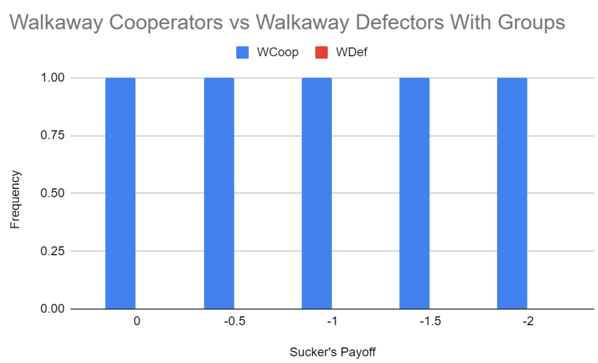
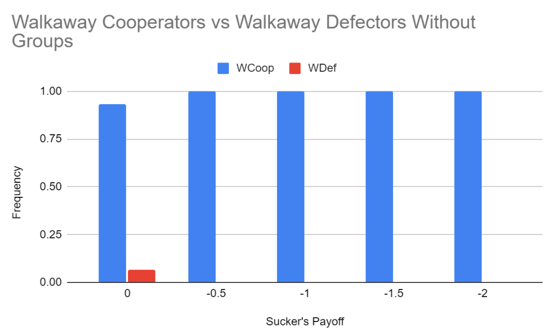


Figure 2.1



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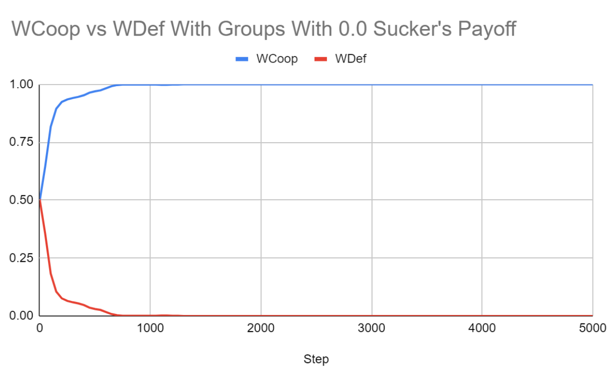

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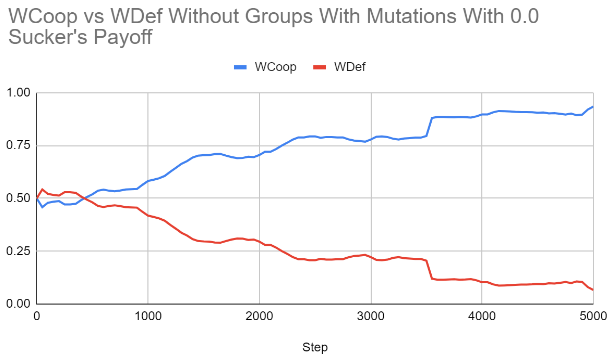

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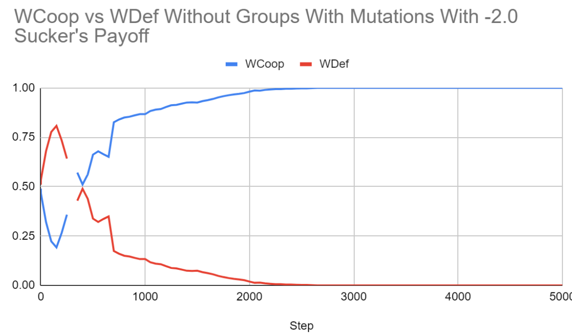

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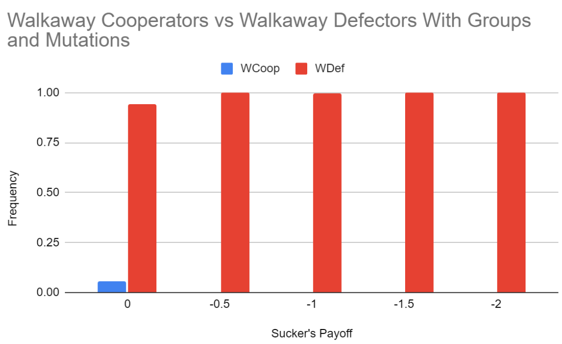

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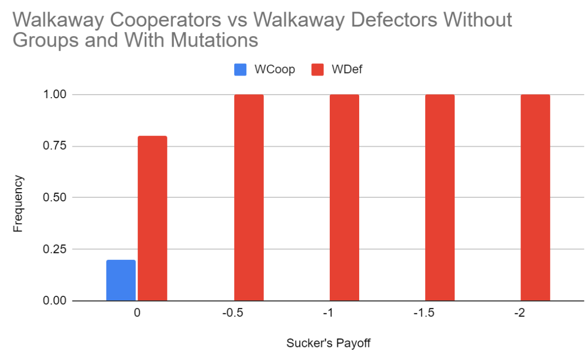

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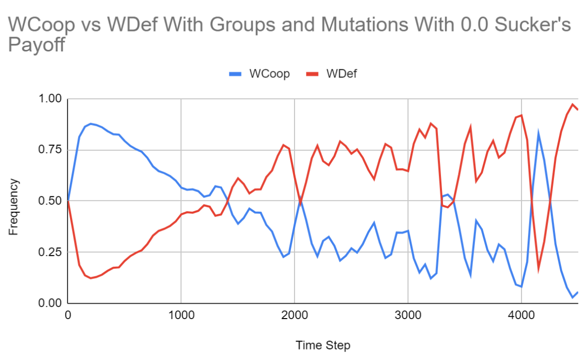

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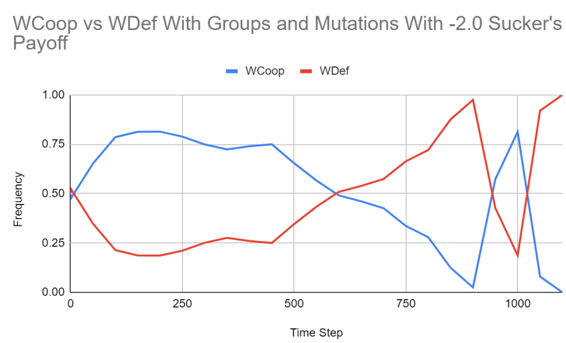

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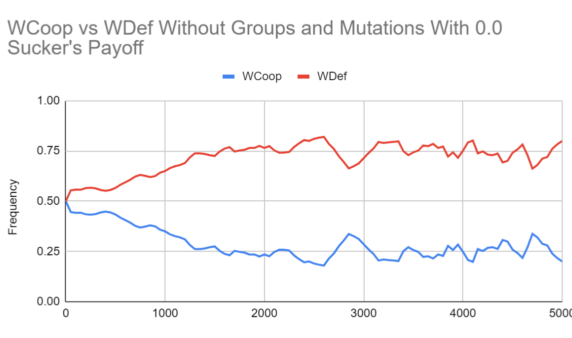


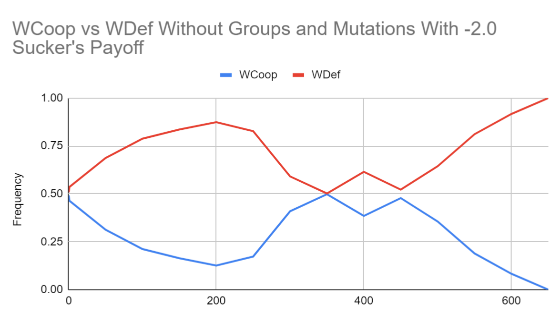


Figure 2.12 **Figure 2.13**

Discussion:

The walkaway cooperators wiping out the walkaway defectors when there were no mutations can be explained because when the walkaway cooperators would interact with a walkaway defector they would immediately move away. The walkaway defectors could not prey on the walkaway cooperators which meant they would be pushed to the edges of groups of walkaway cooperators. When groups were disabled and the sucker's payoff was 0 it did not allow the walkaway cooperators to continuously interact with each other which allowed some walkaway defectors to survive. When mutation rate was upped to 0.01 the walkaway defectors would do better because of the mutations. When groups were enabled the walkaway cooperators started off well which can be seen in Figure 2.9 and Figure 2.11, but would quickly be overtaken especially when there was a harsh sucker's payoff. Disabling groups made it even worse for the walkaway cooperators from the start because they could not rely on making a group with fellow walkaway cooperators.

Topic #3: TFTMobile vs. Walkaway Defectors

Intro:

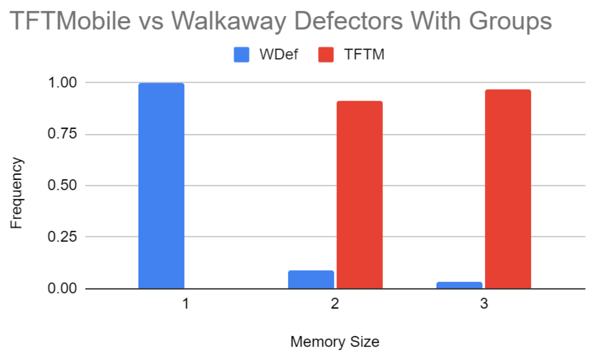
The third set of simulations tested the mobile TFT strategy with the walkaway defectors. Different memory sizes were used to see how much of an effect the memory of the mobile TFT has on its success against the walkaway defectors. Our original hypothesis was that the mobile TFT agents would be more and more successful as the memory size increased, because if the mobile TFT agents knew that the walkaway defector would defect then they could defect as well and force the walkaway defector to leave.

Methods:

To run these simulations 500 mobile TFT agents were placed against 500 walkaway defectors. Mutation rate was set to 0.01 and the sucker's payoff was set to -1.0. The parameters that were varied were enabling and disabling groups and testing memory sizes of 1, 2, and 3.

Results:

The first thing that can be noticed was that groups being enabled or disabled made almost no difference. Walkaway defectors were successful at wiping out the mobile TFT agents when memory size was set to 1 as seen in Figures 3.1 and 3.2. The mobile TFT agents were close to 100% of the population when memory size was greater than 1. When memory size was at its largest at 3 the mobile TFT agents quickly wiped out the walkaway defectors as seen in Figures 3.4 and 3.6.



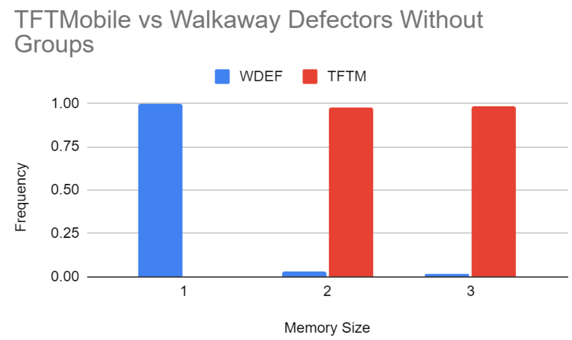
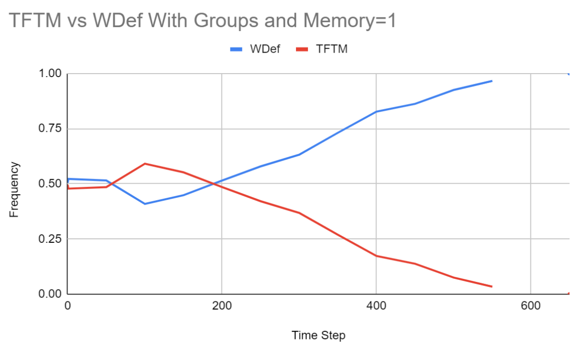


Figure 3.1

Figure 3.2



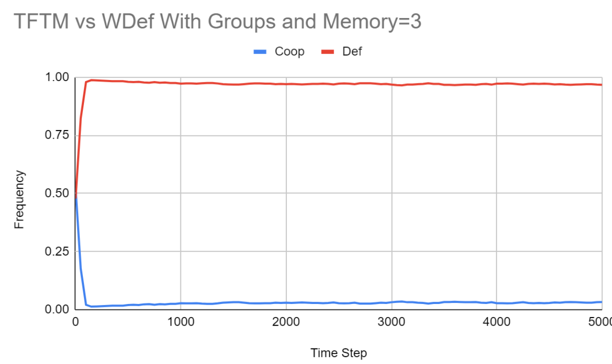


Figure 3.3

Figure 3.4

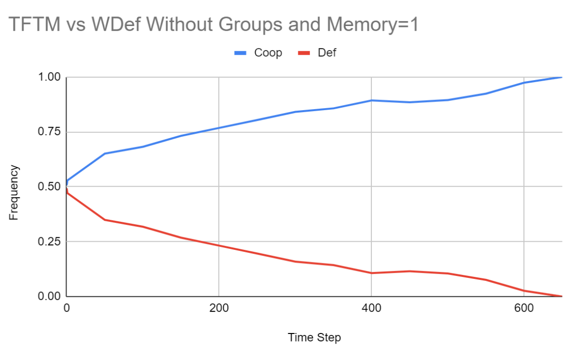


Figure 3.5

Figure 3.6

Discussion:

A possible reason for why groups being enabled or disabled made no difference could be because the walkaway defectors were always moving when they met either another walkaway defector or a mobile TFT agent that remembered the walkaway defector. The walkaway defectors wiped out the mobile TFT agents when memory size was set to 1 because the mobile TFT agents can't remember to defect against the walkaway defectors and get taken advantage of over time. When the mobile TFT agents do have a better memory this allows them to defect against walkaway defectors and possibly cooperate with other TFT agents. With a very large memory the TFT agents can quickly find other TFT agents to work with and the walkaway defectors will have no other agents to take advantage of.

Topic #4: Compare all strategies

Intro:

In the next simulation all strategies were tested against each other. Different memory sizes were used to see how the TFT and PAVLOV agents would fare against the simpler agents that don't have memories. Our hypothesis was that at low memory sizes the walkaway agents would do the best because they use a strategy that does not require memory, but can still be successful. When memory size was increased the more advanced TFT and PAVLOV agents would succeed.

Methods:

To run these simulations 100 agents each of cooperators, defectors, walkaway cooperators, walkaway defectors, mobile TFT, stationary TFT, mobile PAVLOV, and stationary PAVLOV were placed into the simulation. Different memory sizes were tested with values of 1, 2, and 3 and each of these values was tested with both groups enabled and disabled. The sucker's payoff was set to -1.0 and the mutation rate was set to 0.01.

Results:

When the memory size was set to 1 and groups were enabled the walkaway defectors wiped out every agent that had a different strategy. When groups were disabled the outcome was different with walkaway cooperators being the largest group and walkaway defectors being less than 5% of the population. Cooperators, and the mobile versions of both PAVLOV and TFT were the other groups with significant populations by the end. Defectors and the stationary versions of TFT and PAVLOV didn't do well in any of the simulations. Mobile TFT agents were the largest group in all cases where memory size was above 1. The mobile PAVLOV agents did well in most cases being just behind mobile TFT. Walkaway cooperators also managed to have a good amount of agents by the end and cooperators did as well in cases where groups were disabled.

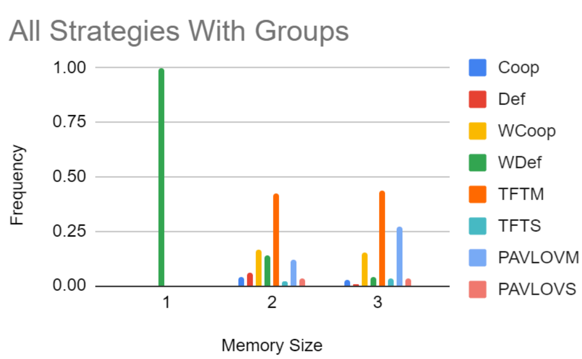


Figure 4.1

Figure 4.2

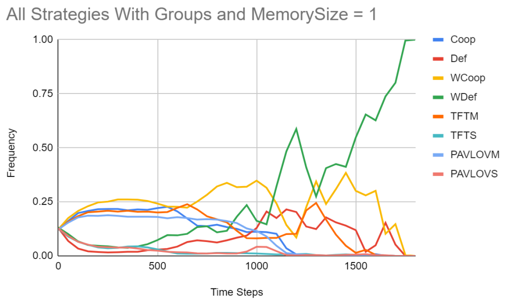
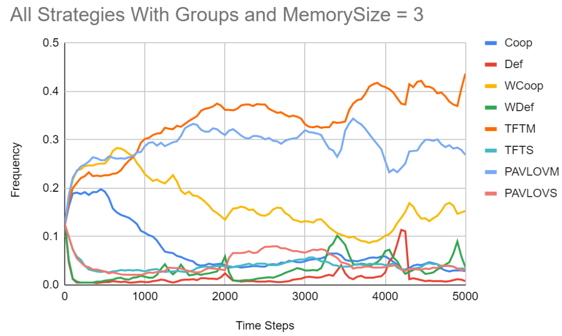


Figure 4.3



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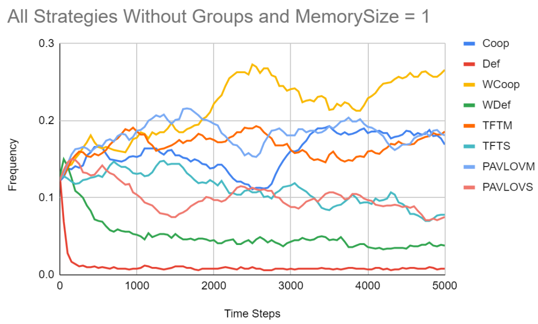

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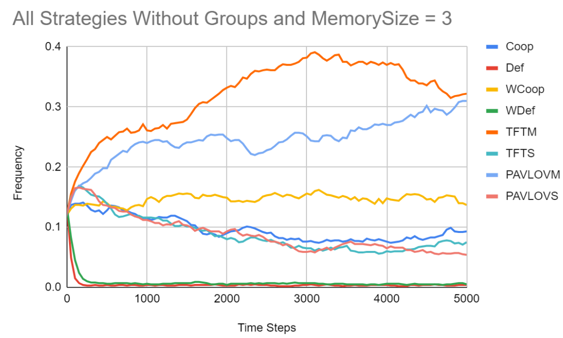


Figure 4.6

Discussion:

Walkaway defectors most likely did well when there was a memory size of 1 and groups enabled because they could join a group and interact with different agents each time step without being remembered. When groups were disabled they may have done worse because they could not find a group of cooperators to easily manipulate. When memory was increased the mobile TFT and PAVLOV agents did well because they could often make decisions based on what the other agent is most likely to do and whether groups are enabled or disabled doesn't have much of an effect on that. The mobile versions did better than the stationary versions because moving to be able to find a partner or group is helpful. The TFT agents may have done slightly better than the PAVLOV agents because when another agent defects against them then they will defect as well, whereas when PAVLOV agents are defected against they may switch to cooperating if they were already defecting previously which could hurt them if matched up with the same defector in the next round.

Topic #5: PAVLOV vs. TFT

Intro:

For the final tests we simulated both the mobile and stationary version of the TFT and PAVLOV strategies. There were two questions that would hopefully be answered through these tests which were as follows. Is there a better strategy between TFT and PAVLOV? How do the mobile versions do in contrast to the stationary versions?

Methods:

To test these questions 250 agents each of mobile TFT, stationary TFT, mobile PAVLOV, and stationary PAVLOV were placed into the simulation. The parameters that were varied were whether groups were enabled and disabled, along with changing the sucker's payoff between 0 and -2.0 at increments of 0.5. The mutation rate was set to 0 and memory size was set to 3.

Results:

The simulations with groups enabled and disabled gave very similar results and there also wasn't very much difference as the sucker's payoff was changed. The mobile version of both TFT and PAVLOV did about equally well and the stationary versions of each were almost always wiped out. When groups were disabled it took longer for the stationary versions of each strategy to be wiped out, but eventually they were wiped out.

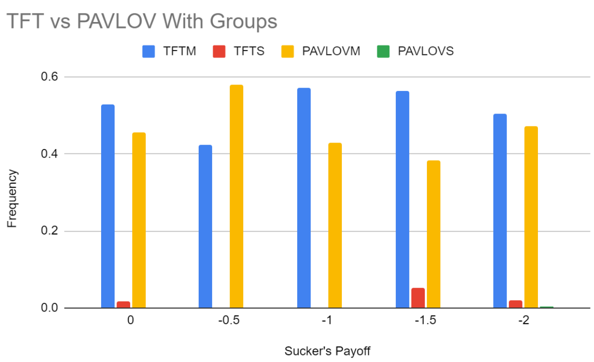


Figure 5.1

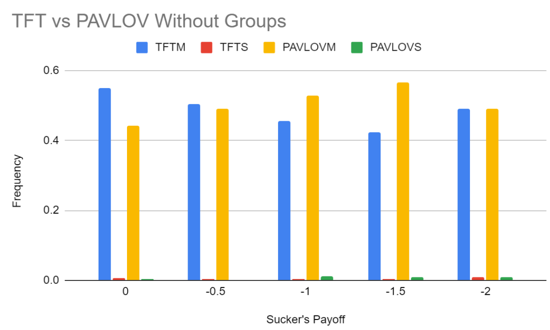
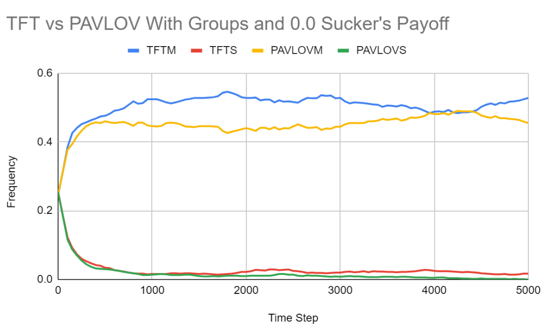


Figure 5.2



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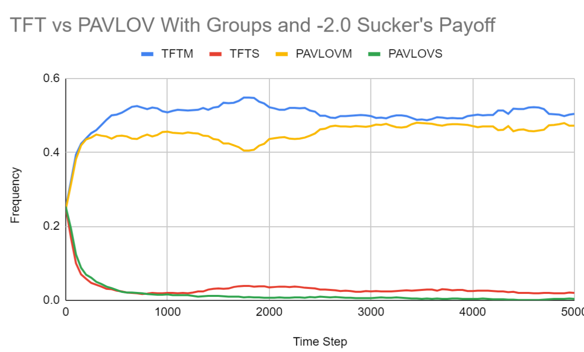
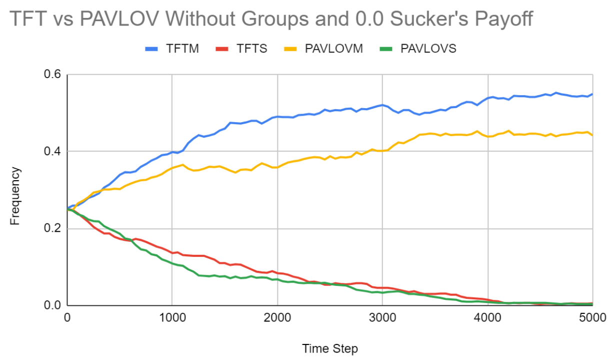


Figure 5.4



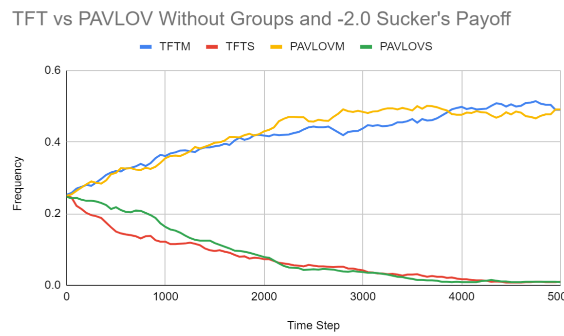


Figure 5.5 **Figure 5.6**

Discussion:

The mobile versions of each strategy were obviously better equipped to survive because they were allowed to move to find partners to interact with. When there were no groups the stationary versions had a better chance of interacting with other agents because agents as a whole were more spread out. Both TFT and PAVLOV strategies did equally well most likely because once the agents started cooperating with each other they would all continue to cooperate. Also if a PAVLOV defector ran into another defector then they would switch to cooperate which gave them a better chance of finding a group that they could continuously cooperate with. There didn't seem to be a strategy that was better from these tests.

General Discussion

How did the results you found in the above simulations compare with those reported by Aktipis?

When comparing the results of these simulations to those reported by Aktipis the results are pretty similar. The walkaway cooperators beat out the walkaway defectors in both our simulation and in Aktipis'. Something that was also similar was the success of the mobile TFT agents as they often ended up as the majority of the population in our simulations. One difference was that the walkaway cooperators were very successful in Aktipis' study when placed against all other strategies. In our simulations the walkaway cooperators were often beat out by the mobile TFT unless memory size was set to 1.

Does increasing the cost of the sucker's payoff help cooperators when faced with walkaway defectors?

When cooperators were placed against walkaway defectors the cooperators did increasingly well as the sucker's payoff cost increased. When the sucker's payoff was set to 0 the population of cooperators and walkway defectors tended to be even, but when the sucker's payoff cost was increased the cooperators were able to wipe out the walkway defectors when there were no mutations. When there were mutations the walkaway defectors were able to win out against the cooperators.

Does memory size matter for TFT?

When memory size was tested with the TFT agents it was found that memory size had a large effect on the performance of TFT agents. With a small memory size of only one the TFT agents were often wiped out, but as the memory was increased the TFT agents did very well. Even as little of a change as increasing memory size to 2 made a big difference for the TFT agents.

What did you find that was interesting in the study you designed?

In the 5th set of simulations where both PAVLOV strategies and both TFT strategies were put into the tests it was very interesting how groups affected the simulations. When groups were enabled the mobile versions of the PAVLOV and TFT strategies very quickly wiped out the stationary versions of both strategies. When groups were disabled the stationary versions survived for much longer.

Future directions: What are at least two questions you would like to investigate further?

In the future it could be interesting to test how agents with different memory sizes in the same simulation would do against each other. For example there could be one TFT agent placed into a simulation with a memory size of one with another TFT that has a memory size of 3. Something else that could be explored further is how the population density affects the results of each simulation.