Final Project Report

This report will talk about the Agent-Based Model with eight different strategies: cooperators, defectors, walkaway cooperators, walkawayDefectors, TFTM, TFTS, PavlovM, and PavlovS. This project investigates several strategies through simulation experiments, primarily focusing on Cooperators vs. Walkaway Defectors, Walkaway Cooperators vs. Walkaway Defectors, TFTMobile vs. Walkaway Defectors, and a comparison of all strategies under different conditions. The central objective is to understand how these strategies perform under varying environmental and game-theoretic conditions, with particular emphasis on the effects of mutation, group, and memory size.

The framework is the Prisoner's Dilemma. In this game, the payoffs are structured initially such that defection is always the rational choice for self-interested players, even though mutual cooperation yields a better collective outcome. This inherent conflict presents a rich ground for exploring how cooperative behavior can emerge and stabilize. Traditional strategies like Tit-for-Tat (TFT) and PAVLOV have been extensively studied for their simplicity and effectiveness in promoting cooperation under specific conditions. The real-world interactions often involve spatial dynamics and the ability to move away from defectors, a factor that can significantly alter the evolutionary outcomes, like the walkaway strategies which utilize movement to avoid repeated interactions with defectors, offering a minimal complexity approach to enhancing cooperation.

Topic #1

For this topic, we want to show the frequency of cooperators and walkaway defectors, find out the performance of cooperators survive on different sucker's payoff, and conclude reasons behind the results. Cooperators cooperate with others. Walkaway defectors defect. If walkaway defectors are defected, they will move to other agents.

For the method, the parameters are below:

Parameter Sweeps 1:

cooperators = 500;

walkawayDefectors = 500;

mutationRate = 0.0;

groups = true, false

cooperate_defector = 0.0, -0.5, -1.0, -1.5, -2.0;

Parameter Sweeps 2:

cooperators = 500;

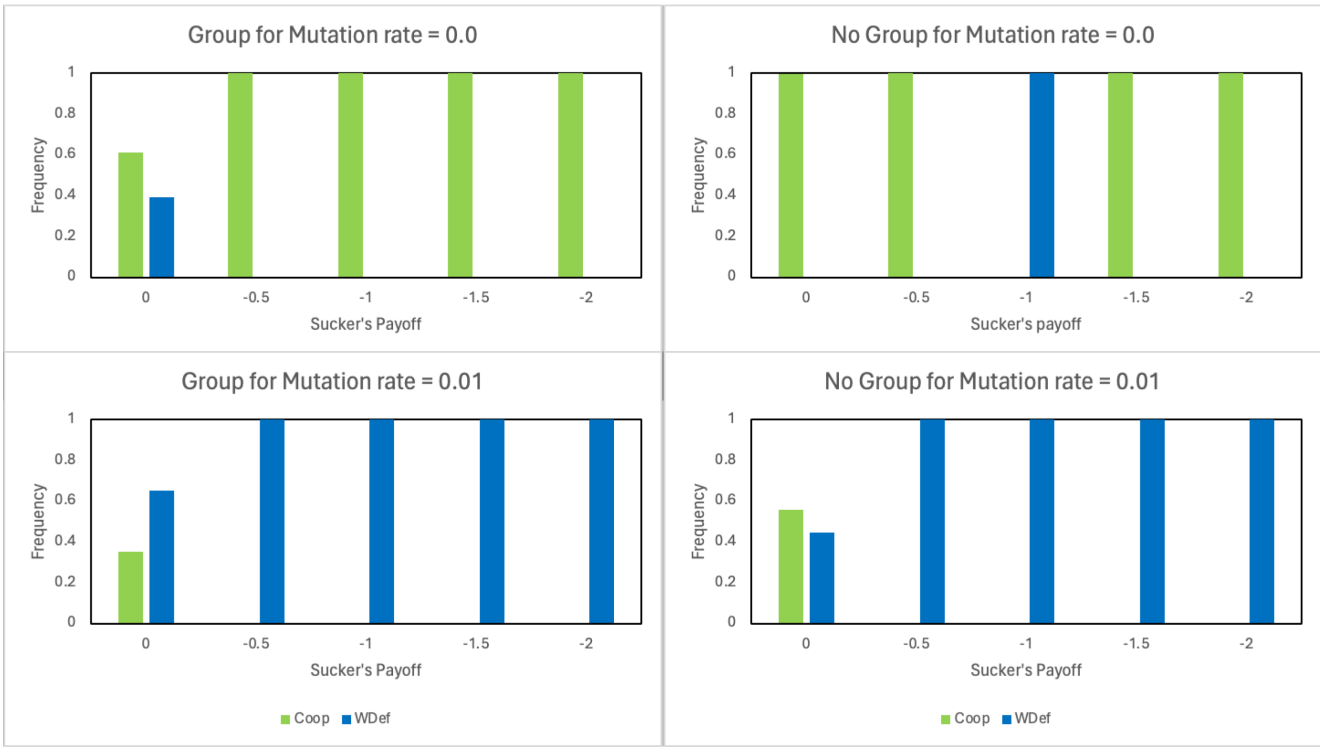
walkawayDefectors = 500;

mutationRate = 0.01;

groups = true, false

cooperate_defector = 0.0, -0.5, -1.0, -1.5, -2.0;

The graphs for the summary results are below. Under no mutation and under group condition, cooperators did a little bit better when payoff = 0 and did much better at the rest of all cases. Under no mutation and under no group condition, cooperators did much better at all cases except when payoff = -1. Under mutation rate = 0.01 and under group condition, cooperators did worse a little bit when payoff = 0 and didn't survive at the rest cases. Under mutation rate = 0.01 and under no group condition, cooperators did a little bit better at payoff = 0 and didn't survive at the rest cases.



Group for Mutation Rate 0.0:

WCoop dominates across all values of the sucker's payoff, except the payoff = 0 since WCoop only does a little bit better.

No Group for Mutation Rate 0.0:

Similar dominance of WCoop across all sucker's payoffs, except the presence of WDef at sucker's payoff of -1.0.

Group for Mutation Rate 0.01:

Significant presence of WDef as the sucker's payoff decreases.

WCoop only maintains a notable presence at sucker's payoff of 0.

No Group for Mutation Rate 0.01:

Dominance of WDef across all sucker's payoffs.

Reduced frequency of WCoop compared to grouping condition.

Walkaway defectors did much better on payoff = -1 on no group condition without the mutation, did a little bit better on payoff = 0 on group condition with mutation, did a little bit worse on payoff = 0 on group condition without the mutation and on no group condition with the mutation rate 0.01, and didn’t survive at the rest cases. The reason why walkaway defectors suddenly do better on payoff = -1 on no group condition without mutation is that no group condition provides chance for WDef to meet and betray more agents under lower payoff value.

Without the mutation, cooperators did better than the situation with the mutation. At a mutation rate of 0.0, the absence of new strategy introductions allows the Walkaway cooperators to dominate. This is because the system remains static without the introduction of new strategies that could disrupt the existing balance.

At a mutation rate of 0.01, strategies may change, leading to a dynamic system where defectors can emerge and exploit cooperators. This results in a higher frequency of Walkaway Defectors, particularly as the sucker's payoff decreases, making defection more attractive. The reason is that mutation rate has the impact to provide agents the chances to separate and defect cooperators, which decreased the frequency of cooperators.

Grouping allows cooperators to cluster and support each other, enhancing the survival and prevalence of Walkaway cooperators even when mutations introduce Walkaway Defectors strategies. The effectiveness of cooperation is thus amplified within groups. Without grouping, the spatial distribution of agents is more random, leading to increased interactions between cooperators and defectors. This enhances the ability of defectors to exploit cooperators, resulting in a higher frequency of Walkaway Defectors. The impact of group condition may be that cooperators may get advantage from no group condition since they have less chance to be impacted by the walkaway defectors.

Higher costs of lower sucker's payoffs make cooperation less viable when defectors are present. This is particularly evident at a mutation rate of 0.01, where Walkaway Defectors becomes more prevalent as the sucker's payoff decreases. When the sucker's payoff is less punitive (e.g., 0), cooperators can still maintain a presence even in the face of mutation.

Topic #2

This study want to analyse the frequency of walkaway cooperators and walkaway defectors, find out the condition that makes walkaway cooperators survive and do better against walkaway defectors, and conclude reasons behind the results. Walkaway cooperators cooperate. If walkaway cooperators are defected, they will move to other agents. Walkaway defectors defect. If walkaway defectors are defected, they will move to other agents.

For the method, the parameters are below:

Parameter Sweeps 1:

walkawayCooperators = 500;

walkawayDefectors = 500;

mutationRate = 0.0;

groups = true, false

cooperate_defector = 0.0, -0.5, -1.0, -1.5, -2.0;

Parameter Sweeps 2:

walkawayCooperators = 500;

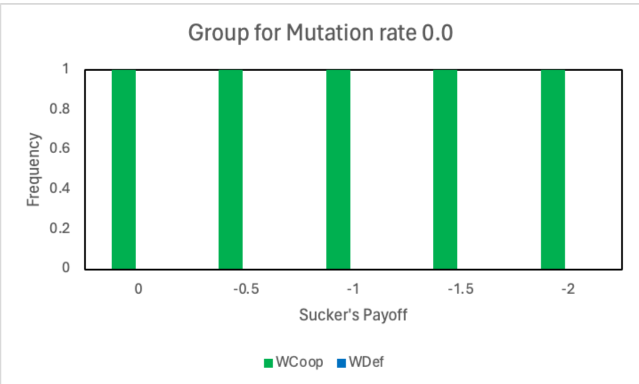
walkawayDefectors = 500;

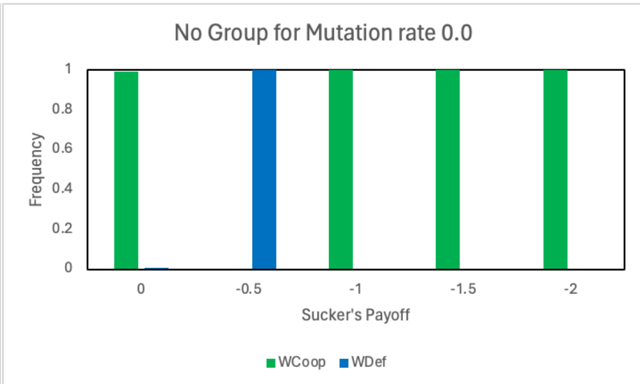
mutationRate = 0.01;

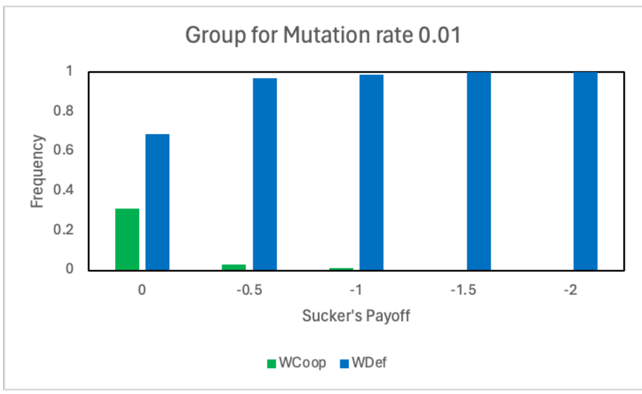
groups = true, false

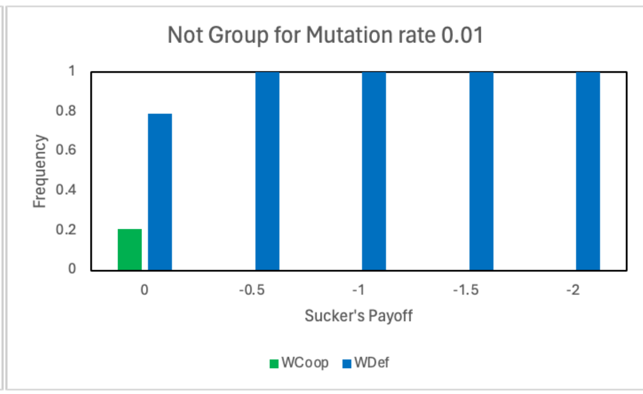
cooperate_defector = 0.0, -0.5, -1.0, -1.5, -2.0;

The graphs for the summary results are below. Walkaway cooperators did better under group condition without mutation rate and under no group condition without mutation rate when sucker's payoff value is not -0.5. Walkaway cooperators survived under group condition without mutation rate, under no group condition without mutation rate when sucker's payoff value is not -0.5, under group condition with mutation rate when sucker's payoff value is 0, -0.5, and -1, and under no group condition with mutation rate when sucker's payoff value is 0.









Group for Mutation Rate 0.0:

Walkaway Cooperators dominate entirely across all values of the sucker's payoff.

Walkaway Defectors do not appear in significant numbers.

No Group for Mutation Rate 0.0:

Walkaway Cooperators dominate across all values, except a completed high frequency of Walkaway Defectors at a sucker's payoff of -0.5.

Group for Mutation Rate 0.01:

Walkaway Defectors dominate across all values of the sucker's payoff.

Walkaway Cooperators have a minor presence only when the sucker's payoff is 0.

No Group for Mutation Rate 0.01:

Walkaway Defectors dominate across all values, with Walkaway Cooperators having a minor presence only when the sucker's payoff is 0.

Without the mutation rate and under the group condition, walkaway cooperators always did better under different amount of sucker's payoff. Without the mutation rate and under the no group condition, walkaway cooperators didn't survive when sucker's payoff value is -0.5 but did better at the rest of situation of sucker's payoff.

With the mutation rate and under the group condition, walkaway cooperators only survived when the sucker's payoff value is 0, -0.5, and -1. With the mutation rate and under the no group condition, walkaway cooperators only survived when the sucker's payoff value is 0. With the mutation rate, walkaway defectors always did better. When the sucker's payoff value is decreasing, the final frequency of walkaway cooperators is also decreasing.

Without the mutation rate and under group condition, walkaway cooperators did better at all cases even though the payoff value was decreasing.

We believe that the reason is that walkaway cooperators can sustain cooperative behavior more effectively under group condition. Under no group condition, the reason for the high frequency of walkaway defectors for payoff value is -0.5 could be that the walkway defectors can exploit cooperators more easily under no group condition. However, walkaway cooperators can still do better since the strategy of walkaway cooperators will leave the walkaway defectors and keep cooperating with the walkaway cooperators under no mutation rate.

With the mutation rate, walkaway defectors generally did better. The reason is that mutation may randomly change the behaviour of agents, which gives walkaway defectors chances to betray and defect other agents. For walkaway cooperators, they may walk away from each other due to mutation, which give the walkaway defectors chances. Walkaway cooperators only survived when the payoff value is high. The reason is that walkaway cooperators can gain the benefit from the payoff value S. When the payoff value is decreasing, the walkaway cooperators can't gain enough benefit so they have less chance to survive. Walkaway cooperators survived most at payoff = 0 since cooperate has no risk due to no payoff for cooperation strategy.

Overall, mutation introduces variability, allowing defectors to exploit cooperators more effectively. The increased mutation rate results in a higher frequency of Walkaway Defectors, especially as the sucker's payoff decreases. Grouping allows cooperators to cluster and support each other, enhancing the survival and prevalence of Walkaway cooperators even when mutations introduce Walkaway Defectors strategies. The effectiveness of cooperation is thus amplified within groups. As the sucker's payoff decreases, the penalty for being exploited increases, making cooperation less attractive and defection more advantageous. This is consistent with evolutionary game theory, where high costs of cooperation reduce the viability of cooperative strategies, leading to the dominance of defectors as observed in the graphs.

Topic #3

We aim to discuss the frequency of TFTMobile agents and walkaway defectors, find out the condition that makes TFTMobile agents do better against walkaway defectors, and conclude reasons behind the results. TFTMobile agents just copy the behaviour of the last partner. If the last partner's behaviour is null, they will move and cooperate. Walkaway defectors defect. If walkaway defectors are defected, they will move to other agents.

For the method, the parameters are below:

tftMobile = 500

walkawayDefectors = 500

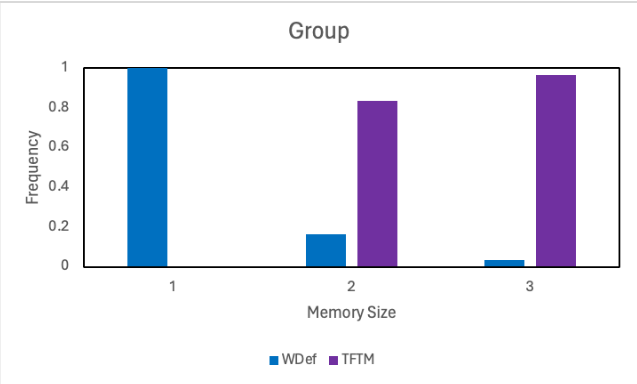
mutationRate = 0.01

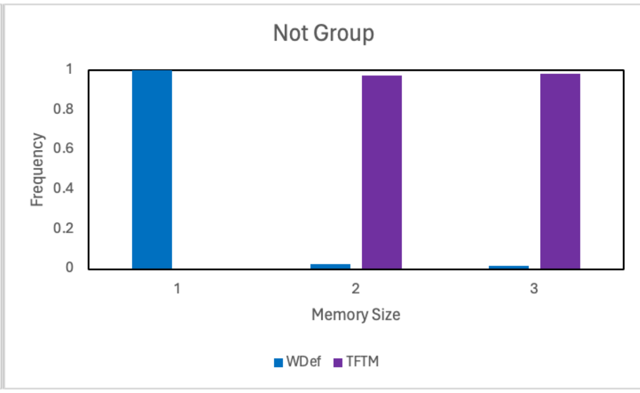
cooperate_detector = -1.0

Group = true, false

memorySize = 1,2,3

For the results, the graphs for summary results are below. TFTMobile did better when memory size is 2 and 3 under both group and no group condition.





Group:

Memory size 1: Walkaway Defectors dominate completely.

Memory size 2: Tit-for-Tat Mobile becomes more prevalent, though Walkaway Defectors still have a presence.

Memory size 3: Tit-for-Tat Mobile dominates completely.

Not Group:

Memory size 1: Walkaway Defectors dominate completely.

Memory size 2: Tit-for-Tat Mobile dominates completely.

Memory size 3: Tit-for-Tat Mobile dominates completely.

For the results:

Memory Size 1:

Group: With a small memory size, agents are limited in their ability to recall past interactions. This favors defectors, as cooperators cannot effectively use memory to avoid being exploited. Hence, Walkaway Defectors dominate.

Not Group: Similar to the grouped scenario, the inability to recall past interactions means defectors have a significant advantage, leading to the dominance of Walkaway Defectors.

Memory Size 2:

Group: With a slightly larger memory, agents begin to remember more past interactions, allowing cooperative strategies like Tit-for-Tat Mobile to gain traction. This leads to an increase in the prevalence of TFTM.

Not Group: Without grouping, the larger memory size still enables TFTM to dominate, as agents can better identify and reciprocate cooperation, reducing the effectiveness of defectors.

Memory Size 3:

Group: With a large memory size, agents can recall and act upon a significant history of interactions. This allows cooperative strategies to flourish, leading to the complete dominance of TFTM.

Not Group: Similarly, the ability to remember past interactions enables TFTM to dominate completely, as cooperators can avoid defectors and preferentially interact with other cooperators.

Overall, memory allows agents to recall past interactions and adjust their behavior accordingly, promoting cooperation. As memory size increases, cooperative strategies can better identify and reciprocate with other cooperators, while avoiding defectors. Grouping facilitates the formation of cooperative clusters, enhancing the success of cooperative strategies. Even with smaller memory sizes, grouping can help cooperators find and interact with each other more frequently, reducing the impact of defectors.

Topic #4

This study aims to analyse all the strategies under different conditions, describe the result, and explain the reasons. Cooperators cooperate. Defectors defect. Walkaway cooperators cooperate. If walkaway cooperators are defected, they will move to other agents. Walkaway defectors defect. If walkaway defectors are defected, they will move to other agents. TFTMobile agents just copy the behaviour of the last partner. If the last partner's behaviour is null, they will move and cooperate. TFTS agents just copy the behaviour of the last partner. If the last partner's behaviour is null, they will cooperate. PavlovMobile agents maintain the behaviour when the partner doesn't defect and to switch the behaviour when the partner defect. If the parters do nothing, the Pavlov Mobile will move and cooperate. PavlovS agents maintain the behaviour when the partner doesn't defect and to switch the behaviour when the partner defect. If the parters do nothing, they will cooperate.

For the parameters:

cooperators = 100;

defectors = 100;

walkawayCooperators = 100;

walkawayDefectors = 100;

tftMobile = 100;

tftStationary = 100;

pavlovMobile = 100;

pavlovStationary = 100;

mutationRate = 0.01;

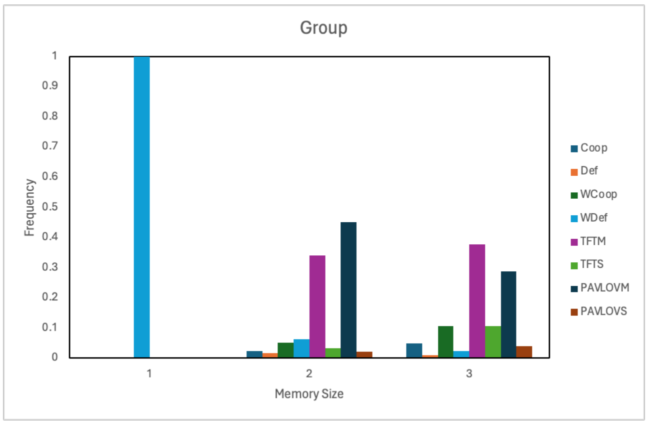
public double cooperate_defector = -1.0;

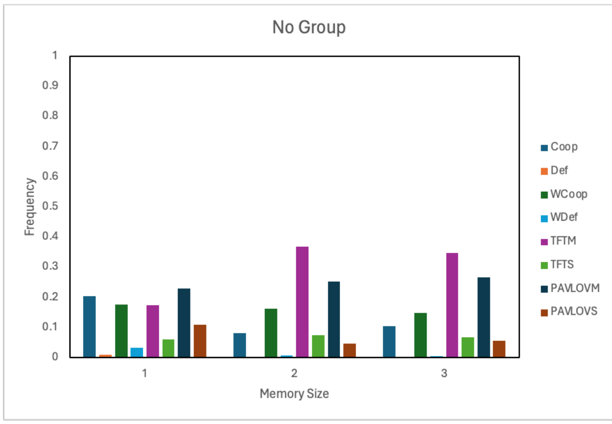
groups = true, false;

memorySize = 1,2,3;

public long simLength = 5001;

The results are below.





Memory Size = 1

In group scenarios, Walkaway Defectors (WDef) dominate, indicating that with minimal memory, defectors can exploit the environment effectively. In no group scenarios, the result is kind of mixture. PavlovM did the the best and defectors did the worst.

Memory Size = 2

In group scenarios, PavlovM and TFTM did better, and defectors did the worst. In no group scenarios, the presence of groups shows a mix, with TFTM becoming more prominent. Defectors did the worst. This suggests that with some memory, TFTM can leverage past interactions to its advantage.

Memory Size = 3

TFTM dominates in both scenarios, highlighting that with larger memory, strategies that can remember and react to past interactions (like TFTM) perform better. PavlovM did good too. Defectors did the worst in both situations.

Walkaway Defectors had a good performance on group condition with low memory size since group condition is good for them to affect and betray more agents. Low memory size didn't allow other agents to remember the defect behaviour so Walkaway Defectors got the advantage.

Generally, TFTM and PavlovM always did the best at higher memory size. Walkaway Defectors thrive in environments with minimal memory, exploiting the lack of historical context. However, as memory size increases, strategies like Tit-for-Tat Mobile, which can leverage past interactions, become more successful, promoting cooperation. Their ability to remember and react to past interactions helps in forming stable cooperative relationships, emphasizing the importance of memory in individual strategy success.

Topic #5

Pavlov Mobile strategy was introduced by Nowak and Sigmund. The basic strategy is to maintain the behaviour when the partner doesn't defect and to switch the behaviour when the partner defect. If the parters do nothing, the Pavlov Mobile will move and cooperate. Walk away strategy means that the agent will leave when the partner defect. Walk away defectors will defect and stay when their partners cooperate.

For our own study, we want to compare the performance of PavlovMobile with the WalkawayDetector under different memory size conditions with group and without group situations. We would like to find out the influence of group condition and memory size towards the success and prevalence of different strategies, like PavlovMobile and WalkawayDetector, in evolutionary games. By understanding the impact of these factors, we can deeply gain the insight into the way of influence from cooperations and defections of agents.

From this study, we want to know the condition that PavlovMobile agents do better than Walkaway detectors and the phenomenon under each condition. Then we want to explain these situations.

For the method, the parameters are below:

pavlovMobile = 500

walkawayDefectors = 500

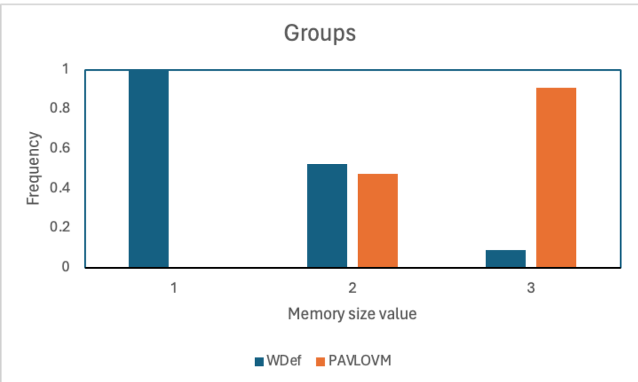
mutationRate = 0.01

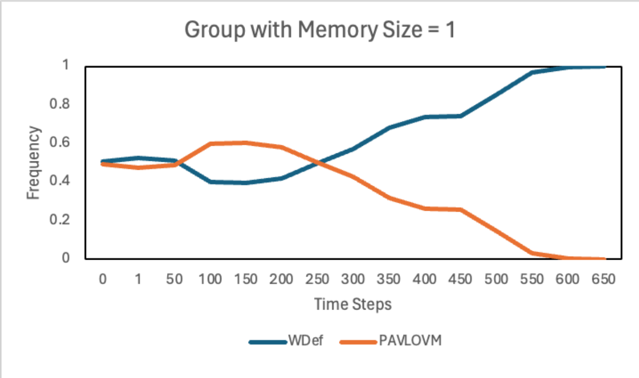
cooperate_detector = -1.0

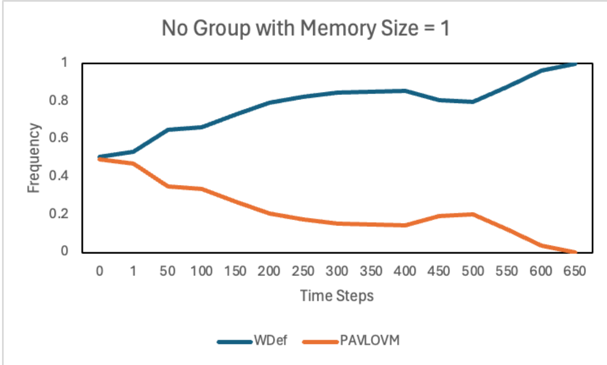
Group = true, false

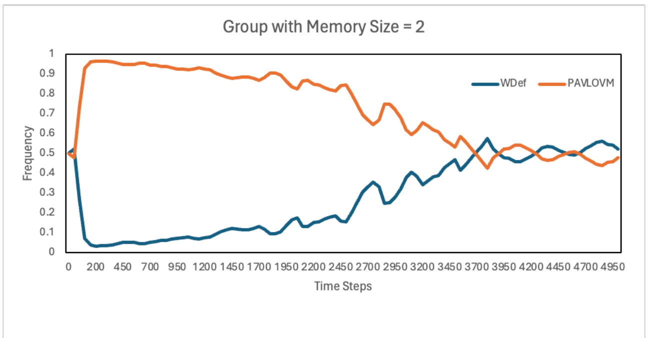
memorySize = 1,2,3

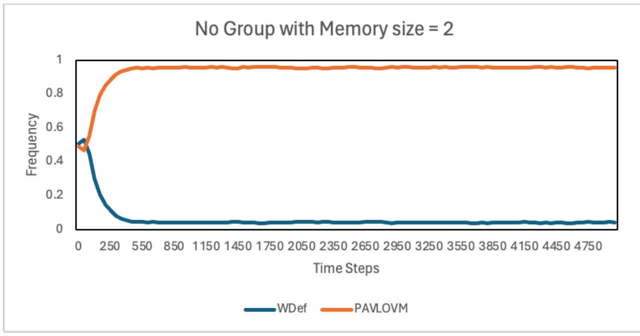
For the results, the graphs for summary results are below. The graphs for detailed results in group condition and non-group condition are below. PavlovMobile agents do better when memory size is 3 under group condition and when memory size is 2 and 3 under no group condition.

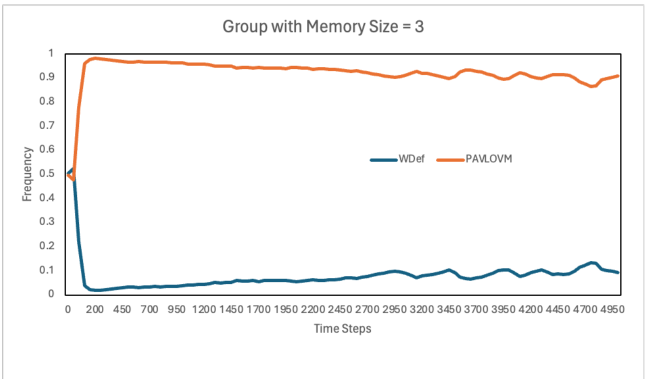


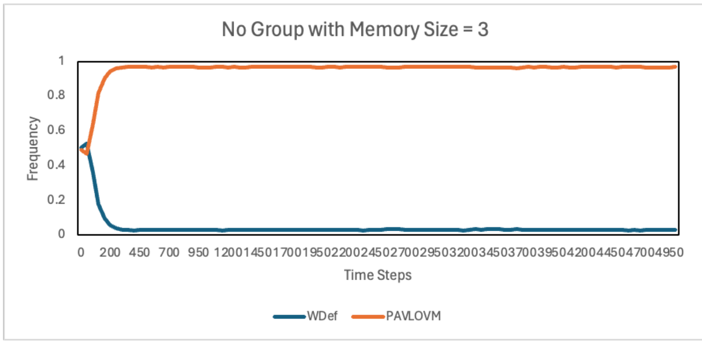












When the memory size is 1, the walkaway defectors always did much better than PavlovMobile agents whether the group condition is applied or not. When the memory size is 2 in group condition, the walkaway defectors did a little bit better than the PavlovMobile agents. When the memory size is 2 in non-group condition, PavlovMobile agents did much better than walkaway defectors. When the memory size is 3, PavlovMobile agents always did much better than walkaway defectors in both group and non-group conditions.

From the detailed result graph, there is a cross point at the very beginning that the walkaway defectors frequency is larger at first but the PavlovMobile agents frequency is larger than the walkaway defectors frequency later. The initial cross point appears in most situations. Under the group condition, after the initial cross point, we noticed that walkaway defectors frequency is always increasing, but PavlovMobile agents frequency is always decreasing. When the memory size is increasing, walkaway defectors frequency increases slower, and PavlovMobile agents frequency decreases slower. Under no group condition, when memory size is 1, we also noticed that walkaway defectors frequency is increasing, and PavlovMobile agents frequency is decreasing without the initial cross point. When memory size is 2 and 3, walkaway defectors frequency doesn't increase, and PavlovMobile agents frequency doesn't decrease after the initial cross point. The reason for the cross point could be that PavlovMobile agents first take the advantage back by changing the strategies.

Under the situation that memory size is 3 and the situation that both memory size is 2 and the group condition is applied, PavlovMobile agents did better. PavlovMobile agents did better with larger memory size. Walkaway defectors showed less sensitivity to the change of memory size since they don't change their own behaviour based on the memory but PavlovMobile agents change their behaviour. Walkaway defectors can increase because walkaway defectors can group together and separate the group of PavlovMobile agents. Since many agents can be in the same location, walkaway defectors can betray more agents quickly.

Under the no group condition, PavlovMobile agents generally did better. When the memory size is high, we noticed the decreasing PavlovMobile agents frequency under group condition but didn't notice that under no-group condition. PavlovMobile agents maintain the high frequency under no group condition when the memory size is 2 and 3. The reason could be that no group condition provide the PavlovMobile agents the ability to move around and maintain advantages at first.

General Discussion

Some of our results are quite different from what Aktipis reported. From Aktipis' report, during the experiment of all eight strategies, walkaway cooperators did the best. However, none of our results showed that conclusion. However, some of our results fit Aktipis' report. When the density is high, TFTM tends to have the best performance.

Increasing the cost of the sucker's payoff value doesn’t always help cooperators when faced with walkaway defectors. In grouped environments without mutation, cooperators benefit more from increased sucker's payoffs as they can effectively cluster and avoid defectors. In non-grouped environments or with the introduction of mutation, defectors gain an advantage as they can exploit the cooperative clusters before they stabilize.

The memory size matters for TFT. For TFTM, we can notice better performance while the memory size is increasing during the study of topic 3. TFTM and TFTS also had better performance in higher memory size in the results of topic 4. The reason is that TFT agents rely on memory to copy the partner’s behaviour. It is important for them to have a larger memory size to survive from other agents.

The interesting thing I found is that some results that the theories can’t exactly explain. For example, in topic 1 under no group condition without mutation, the walkaway defectors did better when the payoff = -1 but didn’t survive in other payoff value situations. When I did another experiment, in the same conditions, the walkaway defectors did better when the payoff = -0.5 but didn’t survive in other payoff value situations. Other interesting thing is that there always exists a cross point at first in the detailed result graph on topic 5, which is not what we expected. It is possible that walkaway defectors take advantage at first, and then PavlovM agents suddenly take over later. This interesting phenomenon will be missed if we didn’t check the detailed result data.

The research evaluates a broad spectrum of strategies within the framework of evolutionary game theory, providing comprehensive insights into their dynamics and effectiveness across different conditions. By including factors such as mutation rates, memory sizes, and group dynamics, the study robustly mimics more complex real-world scenarios, allowing for a deeper understanding of strategic interactions. ABM offers a flexible and powerful tool for simulating complex systems and capturing emergent behaviors that traditional analytical approaches might miss.

However, despite its complexity, the model simplifies some aspects of real-world interactions, such as environmental variability and the full range of possible agent behaviors and reactions. The specific parameter settings and model assumptions may limit the generalizability of the findings to different real-world contexts or other types of games and interactions. The study primarily focuses on immediate outcomes rather than long-term evolutionary dynamics, which might provide different insights into the stability and evolution of strategies. What’s more, the resources and complexity of environment stress are not shown from the study.

Therefore, I have two questions that I would like to further investigate in the future.

How do different strategies evolve under different speed of resource usage? Investigating this could provide insights into the resilience of cooperative strategies under economic or ecological pressures.

What would be the effect of mobility if we can adjust the moving distance that the mobile agents can move? Mobility is also related to real world since the physical distance exists in the real life. The movement rule (win-stay, lose-move) allowed them to avoid defectors effectively and maintain high levels of cooperation. We wonder the influence of the amount of mobility towards different strategies.