EVALUATING MULTIPLE STRATEGIES IN 'n'-PLAYER GAME *The Mind*

Bachelor's Project Thesis

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Abstract: The game "The Mind" is a card game in which players play their (numbered) cards cooperatively, without any communication, in an ascending order. The game is not turn-based, making time the only common variable. However, there are multiple ways of deciding when to play and when not to. For instance based on time passed, probability (simulation) or copying other players. This research presents an agent-based model in Python, that implements "The Mind" and several varying strategies. The model includes the shuriken-card, which is the game's only official form of communication. In this paper we evaluated several strategies based on factors such as effectiveness and realism. We found that the implementation of the shuriken strategy in this study was ineffective. Furthermore, the basic strategy based on counting down the difference seems to be the most effective in general.

1 Introduction

Playing games often allows for, and involves, a great variation of tactics applied by players. There is barely any game, besides gambling games, where strategy does not play any kind of role, as this often represents the exciting and discovering part of any game. Although the game "The Mind" (Warsh, 2018) has such simple rules that variable playing strategies might not directly come to mind, there certainly are different ways of playing it.

"The Mind" is an n-player card game ($n \in [2,4]$) where the players have a shared task. Each player receives a number of randomly selected cards in the range [1,100] equal to the current level number. The common goal of the players is to play all of the dealt cards among all players in ascending order without any form of communication, while a player's cards are also hidden from the others. This game is not turn-based, which means the players are free to play only their lowest card at any time they deem appropriate (Warsh, 2018). Table 1.1 shows how the game is set up at the start of a game, based on the amount of players. In game, playing the wrong card (not the lowest subsequent card of the distributed cards) means losing a life. Furthermore, all cards lower than the (wrongly) played card are discarded. The game is lost whenever the players have no lives left. Contrarily, if the last level has been completed with any number of lives left, the players have won the game. Lastly, the game also contains shuriken-cards. Any player at any point in the game can propose to play this card. If everyone agrees to play a shuriken, each player shows and discards their lowest card. During the game the players can earn back lives and shuriken. Passing levels 2, 5 and 8 adds another shuriken to the game. Passing levels 3, 6 and 9 gains the players an extra life.

Players	Levels	Lives	Shuriken
2	12	2	1
3	10	3	1
4	8	4	1

Table 1.1: Starting setup "The Mind" for different number of players.

Earlier research by Windt (2022), O'Callaghan (2022) and Theuwissen (2022), has shown ways of modeling game strategies by using cognitive as well as logic- and agent-based models. However, these studies involve research on homogeneous groups groups of agents and have not made an attempt yet at modeling the shuriken card. This study aims to answer the question: What is the effect of different playing strategies and the shuriken card on performance in the game "The Mind"?

To provide some insight on this topic, an agent-based model with multiple strategies for "The Mind" and an implementation of the shuriken card are presented and evaluated. Depending on the experiment, the performance is measured in terms of win percentage, number of mistakes, and lives left. It should be noted that of these variables, win percentage can be regarded as the most valuable, as the number of lives left does not affect the game score. The model section contains a detailed description of the implementation of the entire game structure as well as the several strategies. The experiments are presented in the analysis section and discussed in the conclusions section, which also contains potential future research directions. They include a presentation of the effect the shuriken implementation has, and an evaluation of the different playing strategies.

2 Model

The goal of our research was to evaluate the effects of several strategies and the shuriken on the overall game. Thus in the following sections, we will discuss the implementation choices we made for the simulation of the game in general. This includes how the levels are set up, and what strategies were implemented to create a diverse agent set.

2.1 Structure

Setup: A game class was implemented which constructs the framework with either 2, 3 or 4 unique agents and the corresponding lives and shuriken as in Table 1.1 and initializes new levels when necessary. The game is then run until either the levels are over or the number of lives has run out.

Rounds: At the start of level n, each player receives a random selection of n unique cards. The players sort the cards themselves in ascending order and the level is run while there are cards in the game and it has not yet been lost.

At this point, we have made the implementation choice to present players with a number of intervals at which they can decide to play their lowest card. The use of intervals allows the players to continuously reconsider playing a card while time is running, we chose this option considering the continuous contemplating that goes paired with this game according to informal observation. The intervals are reset every time a card is played and max out at the highest possible difference between the pile and a card (being 100). This is only a theoretical limit, in practice, agents will always play before the max interval is reached. For each interval, the waiting time of each player is collected and when one of these values is lower than the playing threshold (threshold=1) or the maximum interval is reached, the player with the lowest waiting time proceeds to play their card. Subsequently, the pile is updated, the model checks if a mistake was made and each player is given the opportunity to propose a shuriken. This moment was chosen, because at this point in time the card distribution has changed, which makes it an optimal point to reconsider playing a shuriken. Further information on the shuriken implementation can be found at Section 2.3.

Mistakes: If a player has a card with a value lower than the card that was played, a mistake was made. All cards lower than the played card are removed and the players lose one life (regardless of the number of removed cards). Each player may also adjust their current tactic based on the mistake that was made. Section 2.2 describes how this is implemented.

2.2 Agents

Multiple agents with varying strategies were designed and as these agents have a number of shared methods, a super class was also created. Each sub-agent inherits these methods, while some overwrite the original to design their own strategy. The following agents with their own strategies were created:

- The Basic Agent
- The Uncertain One
- The Copy Cat
- The Statistician

- The Mathematician

In the implementation of each strategy we differentiate between an active and a passive strategy. The active strategy (A) is the basic strategy which calculates the waiting time in game. The passive strategy (P) is a modifiable part of the active strategy which has no effect on the active strategy at the start of the game. When mistakes are made, some agents will adjust this passive value (P) to avoid making more mistakes.

2.2.1 The Super Agent

This superclass consists mostly of methods that provide simple functionalities:

- Sorting cards
- Removing the lowest card
- Calculating the difference between the pile and the lowest card in hand
- Calculating the average difference between an agent's cards

The class also contains methods concerning the shuriken strategies (see Section 2.3) and methods to cover the general passive strategy for each agent.

As all strategies are based on counting but as humans generally do not count at the same speed, each agent also has a unique counting speed (s) in the range [0.8,1.2]. This variable also differs within agent strategies.

General passive strategy: The passive strategy (P) is adjusted when mistakes were made. Either when an agent threw their card too fast, or if the agent was too slow and should have played earlier. In case of a mistake we can distinguish between three possible types of agents:

- Agent A: Played their card too fast
- Agent B: Should have played earlier
- Agent C: Not directly involved in the mistake

For agent C we did not include an adjustment for P as they are not immediately involved and we agreed there was no apparent adjustment strategy. The equations for adjustments are generally the same for each agent, however an adaptability (a) variable was multiplied within the formula that differs across agents. For normal adjustment we chose $a = 0.25$ as it is assumed the player who made a mistake also adjusts. This assumption corresponds to research by Windt (2022) which showed that relatively careful adjustment is useful, as greater adjustments lead to both players overcompensating and never reaching an equilibrium. If an agent is more flexible in their adjustment strategy, the adaptability is doubled ($a = 0.5$). Using this higher adaptability, we intend to model the larger flexibility and adaptability shown by some players in informal observation of The Mind gameplay. Furthermore, we want to investigate the level of potential over-adjustment using such a high adaptability.

Agent A: Equation 2.1 is based on the principle that if a wrong card was placed on the pile, the agent should play slower and P should increase. When a wrong card is played, the only information this agent has is the card that should have been thrown (c_t) for every card that gets discarded and the current card on the pile (c_p). Therefore, we decided to base the adjustment on that information. This strategy updates for every card that is discarded. This strategy deviates from the adjustment strategy used by Windt (2022), which used a fixed interval to slow down or speed up the playing speed. The goal of this strategy is to use the information from the (discarded) cards in order to make a suitable and flexible adjustment, and avoid overcompensation to reach an equilibrium.

$$P = P + (1 - \frac{c_t}{c_p}) * a \tag{2.1}$$

Agent B: Equation 2.2 shows the adjustment in P for an agent that should play faster. The only information this agent has access to is his own estimation of when he would have played his card (i_p), and the interval at which the wrong card was played which should be the goal interval (i_g).

$$P = P - (1 - \frac{i_g}{i_p}) * a \tag{2.2}$$

We considered that in a next identical instance, ideally, this player would throw their card (potentially for multiple cards) before the other player did. Therefore, the adjustment is based on that information in a similar way as Equation 2.1. The use of intervals seemed more useful in this situation than using cards as it contains more information about the strategy of the other agent.

2.2.2 The Basic Agent

Active strategy: This agent represents the most basic and simple strategy. The active strategy (Equation 2.3) of this agent consists of counting down the difference between their lowest card and the last card played (Δd). The agent, when deciding which interval to play in, picks a random number from a normal distribution. The standard deviation (σ) of the distribution is 0.1. Realistically, a player does not count accurately or consciously, but rather estimates. Therefore, a relatively high standard deviation of 0.1 is plausible.

$$A = N(\Delta d * s * P, \sigma) \tag{2.3}$$

Passive strategy: The Basic Agent has a passive strategy so $P = 1$ will be updated and affect the active strategy accordingly. This agent has a standard adjustment strategy, meaning the adjustment variable $a = 0.25$.

2.2.3 The Uncertain One

Active strategy: This agent bases uses the same strategy as discussed in The Basic Agent. While the agent also bases their active strategy on the difference between its lowest card and the last card played, the standard deviation increases as time passes, simulating an uncertain agent. This variation in the standard deviation corresponds with findings in research by Theuwissen (2022), which stated that "timing becomes less precise for longer time intervals". As can be seen in Equation 2.4, when the intervals (i) pass, the deviation gradually increases with a natural logarithmic function, which we considered to be the best fit for modeling the increasing uncertainty. This increasing value is flattened by dividing the value by 10, in order to not let the standard deviation, and thus uncertainty ascend excessively.

$$A = N(\Delta d * s * P, \sigma * (1 + \frac{ln(i+1)}{10})) \tag{2.4}$$

Passive strategy: As this agent is uncertain, he is quite susceptible to adjustments and the adaptability $a = 0.5$.

2.2.4 The Copy Cat

Active strategy: The initial active strategy for this agent is the same as the basic agent. However, as the game is played, this agent will replicate other agent's actions. As the agent does not have access to the internal decision making processes, it copies the speed at which other agents play by keeping track of a speed coefficient (k). The initial value $k_0 = 1$ is updated every time a card is played by another agent as shown in Equation 2.5

$$k_0 = 1, k_m = \frac{1}{m+1}(\sum_{x=0}^{m-1} k_x + \frac{i_p}{\Delta d}) \text{ for } m > 0, \tag{2.5}$$

, where $m =$ the number of adjustments that have been made, which happens whenever a card has been played. Note that for each adjustment m the value is averaged over $m+1$ because we also factor in $k_o = 1$. In Equation 2.5, if the played interval (i_p) for an adjustment is bigger than the the difference between the card that was played, and the card that was on the pile (Δd) the coefficient will increase. An increase in k will in turn increase the interval at which the Copy Cat would play their card (Equation 2.6). If, however, i_p is lower than Δd the k will be updated with a value lower than 1, and decrease.

The coefficient is a factor in the active strategy (Equation 2.6) to replicate the actions of other agents in further decision making.

$$A = N(\Delta d * k * s * P, \sigma) \tag{2.6}$$

Passive strategy: The Copy Cat already attempts to copy the other agent's strategy, therefore there is no additional adjustment when a mistake was made.

2.2.5 The Statistician

Active strategy: The Statistician decides on playing at interval 1 by simulating random potential cards distributions (for 100 repeats) from the total distribution based on their knowledge of the cards in play. It uses the statistical probability that the outcome of playing in each repeat is favorable to determine in which upcoming interval it should plan to play their card. Based on the probability that there exists a card in play that is lower than his own lowest card (p_l) the agent estimates the correct interval (γ) to play their card by multiplying with the remaining possible cards ($100 - c_p$) as shown in Equation 2.7. The integer function is used to truncate the number to match the interval values.

$$\gamma = integer(p_l * (100 - c_p) * s * P) + 1 \quad (2.7)$$

When this interval is reached the agent will play their card.

Passive strategy: This agent has a standard adjustment strategy ($a = 0.25$).

2.2.6 The Mathematician

Active strategy: This agent also bases its decision on probabilities, using Equation 2.8. This strategy follows related research by Theuwissen (2022), which stated that a participant in their experiment used probability calculation as a playing strategy. The number of favourable outcomes o_f, being the number of cards in play that are higher than the agent's lowest card, are divided by the total number of possible cards o_p. This procedure is done for the number of cards n_c in the hand of other players.

$$p_{play} = (\frac{o_f}{o_p})^{n_c} \quad (2.8)$$

The agent than uses this as a weight to play (p_{play}), and the weight to wait ($p_{wait} = 1 - p_{play}$) for each interval to choose whether to play or not, making a random choice based on these weights.

Passive strategy: This agent has no passive strategy, as it was not implemented.

NB: This strategy turned out to be so ineffective that after some testing, we decided to exclude if from further analysis.

2.3 Shuriken

If a shuriken is proposed, all players are allowed to reject and only if every player agrees, the shuriken is played. Informal observation of The Mind gameplay suggests that an effective way to use a shuriken is by using a shuriken whenever the cards in a player's hand are similar, meaning the average difference between the cards is quite low (e.g. [74,77,80,82,89]). Playing a shuriken at this time would allow the player to play their cards in continuance more efficiently.

The process for shuriken is the same for each agent and consists of three parts:

1. Proposing a shuriken
2. Accepting or rejecting a shuriken
3. The Shuriken-phase

2.3.1 Proposal

As established before, the shuriken strategy we implemented is based on the average difference between face values of the cards in hand ($avg\Delta d$). After each played card the agent calculates their $avg\Delta d$. If this value is lower than a predetermined lower threshold (t_l) it proposes a shuriken to the other agents. Another requirement for a proposal is the number of cards in hand. The agent only proposes if it has more than 4 cards, in order to avoid wasting a shuriken with little effect on very few cards.

2.3.2 Reaction

Not until every agent accepts the proposal for a shuriken a shuriken is played. If the difference is below a predetermined upper threshold (t_u) the other players will accept the shuriken.

2.3.3 The Shuriken-phase

Playing a shuriken is one way for the agents to communicate. We considered different types of information that can be communicated and chose to implement the information that seemed most apparent, as we considered other subtle information to not be realistically programmable in the context of our model.

The information we chose to communicate was: if a shuriken is played, the agents know the other players do not have cards lower than the card that they discarded.

This allows the agents to play their own cards below the subsequent higher values in quicker succession. Thus, for as long as the agents have cards lower than a card that has been discarded as a result of the shuriken they gain a multiplication variable (that is dependent on the relative value of their discarded card), which gradually decreases their reaction time to simulate the consequence of the information.

For some clarity, here is an example with three players where a shuriken is played. The combined agent, discarded-card sets are: [(A, 13), (B, 24), (C, 44)]. As a consequence, the multiplication variable, which equates to playing speed of every agent is adjusted to: [(A, 0.5), (B, 0.75), (C, 1)], as agent A had the lowest discarded card and thus can play the fastest, then B and then C. If at one point agent A's lowest card > 24 (the next discarded card), agent A matches their playing speed to agent B: [(A, 0.75), (B, 0.75), (C, 1)], and so does every agent until everyone's lowest card > the highest discarded card (in this case 44) and everyone is back to their original multiplication variable of 1, that does not affect the playing speed. The starting difference with playing speed of 0.25 was found to yield the best performance for the shuriken strategy in trial runs using different values.

3 Analysis

For the analysis of our program four experiments were set up for different purposes.

3.1 Experiment 1: Shuriken thresholds

The goal of experiment 1 is to find the optimal and most effective upper- (t_u) and lower thresholds (t_l) for in the shuriken-phase. In order to find the best threshold combinations we first ran each possible combination in a wide range [1,25] for both thresholds and kept track of the win-percentage for each combination (n = 250 per combination). The number of players as well as strategy types were chosen randomly to get a realistic representation. However, the results showed no clear indication that there was a threshold combination resulting in a better win-percentage. As the shuriken implementation thus did not seem to affect win-percentage, we created a a similar but smaller scale statistic. The shuriken-score, which is based on the number of mistakes (S_m) while in the shuriken-phase (see Section 2.3.3) and the times the shuriken is played (S_p). It makes use of the standardize Equation 3.1, with μ = mean of distribution and σ = standard deviation. For the score, see Equation 3.2.

$$z(X) = \frac{X - \mu}{\sigma} \tag{3.1}$$

$$S_{score} = z(S_p) - z(S_m) \tag{3.2}$$

Figure 3.1 shows the resulting scores per threshold combination, where $t_l \in [5 .. 14]$ and $t_u \in [12 .. 21]$ and n = 1000 per combination. X-axis notation is t_l followed by t_u: 512 shows $t_l = 5$ and $t_u = 12$. The threshold combination with the highest score was $t_l = 14$ and $t_u = 18$, which were the thresholds that were used for the following experiments. Note that t_l is on the edge of our scope. Tests with higher thresholds were considered beyond the scope of this research, as they are not in line with the shuriken hypothesis presented in this paper (Section 2.3) and therefore not included in this analysis.

A remarkable observation from Figure 3.1 is that the score drops substantially at times when the upper threshold is higher or close to the lower threshold. Furthermore, the general trend upwards can be explained by the fact that increasing the thresholds causes the shuriken card to be played more often due to softened conditions.

Figure 3.2 shows the average shuriken-scores for each upper and lower threshold. The steepness of the incline of both graphs shows that the effect of the lower threshold on the average shuriken-score is bigger than that of the upper threshold.

3.2 Experiment 2: Shuriken effect

The goal of experiment 2 is to find out whether the use of shuriken in a game leads to an effective difference in win percentage compared to not using shuriken. After the optimal threshold values were established in Section 3.1 ($t_l = 14, t_u = 18$), the effect of the shuriken can be investigated, using the lower- and upper threshold and n = 1000. The number of players as well as strategy types were again chosen randomly.

	Wins	**Mistakes**	**Lives left**
With	571	3754	1922
Without	573	3760	1940

Table 3.1: A 1000 runs of The Mind, with- and without the implementation of shuriken

Table 3.1 shows the data that was collected. Performing a two proportions two tailed Z-test shows that the proportion of wins for games with shuriken

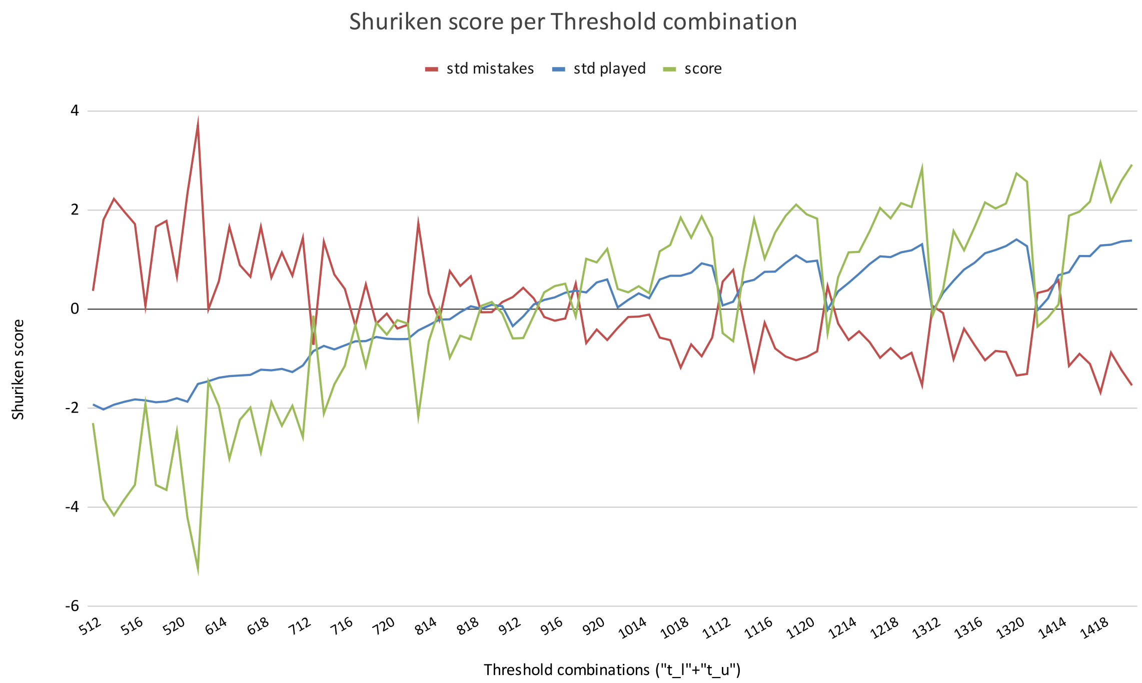

Figure 3.1: Graph showing the shuriken score for each upper- and lower threshold combination

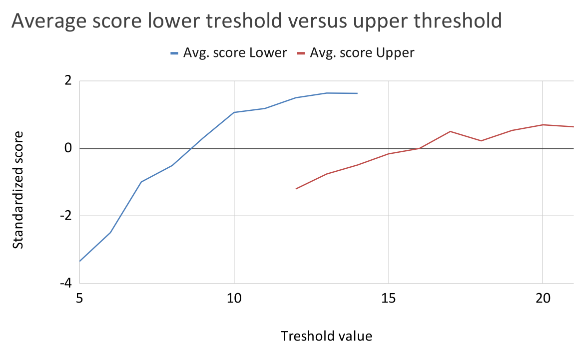

Figure 3.2: Graph showing the average shuriken score for both upper- and lower thresholds

is not significantly different from the proportion of wins for games without shuriken, $z = 4.085, p = 0.964$. The strategy to play shuriken as discussed in Section 2.3 does not effectively improve the chance of winning. Nonetheless, for all following experiments, the shuriken strategy was employed.

3.3 Experiment 3: Uniform group of agents

The goal of experiment 3 is to compare the different implemented strategies and their effectiveness in a uniform group of agents, with a randomly initialized size. The number of wins, mistakes and lives left at the end of the game were collected for every set of agent over a 1000 runs.

Figure 3.3 shows that three agents, the Basic Agent, the Statistician and the Copy Cat have comparable performance. In a uniform group of agents they have a higher win percentage (79.9%, 79.6% and 75.5% respectively) than a random group of agents would have (57.1%). However, the Uncertain One has a lower win percentage, more mistakes and fewer lives left at the end of the game. A game among Uncertain One agents involves a lot of uncertainty, which accounts for the decrease in performance. This research allows for more mistakes than lives lost, as every discarded card is regarded as a mistake, while multiple discarded cards at once cost only one life.

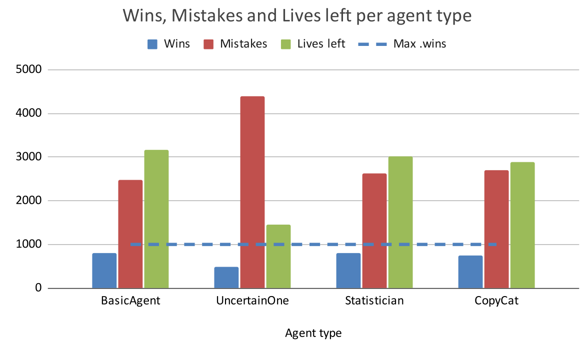

Figure 3.3: Graph showing the wins, mistakes and lives left per uniform group of a certain agent type

3.4 Experiment 4: two player games; different strategies

3.4.1 4a. Win percentage

The goal of experiment 4 is to find out how the strategies play out in two player games were both players have a different strategy. First of all, the win percentage of every agent type against another agent in a two-player game was collected, of which the results can be seen in Figure 3.4 (n = 1000).

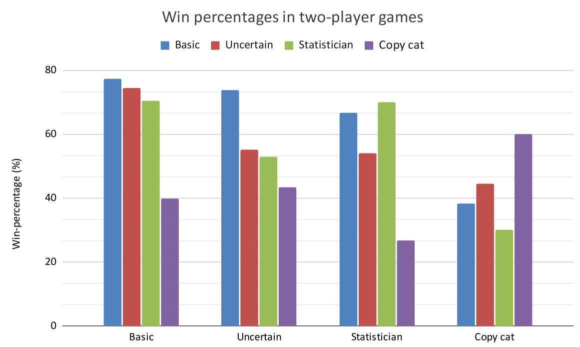

Figure 3.4: Graph showing the win-percentages for two-player games with different strategies

One remarkable statistic out of this graph is the fact that Uncertain One is the only agent type that does not perform best with another agent of its own type, but instead performs better in a two-player game with the Basic Agent. The Copy Cat is the only agent that has a bad performance with Basic Agent. In general, this agent does not perform well in a two player game, except with another Copy Cat. In a two player game, the possibilities to adjust are much lower compared to a three player game. Example: in level six each player has six cards, but the agents own cards are not used to make adjustment. Therefore, in a two player game, the agent will be able to adjust six times, but a three player game has another six possibilities for the additional agent.

3.4.2 4b. Mistakes

A disadvantage of using the win percentage as a statistic in Section 3.4.1 is the fact that it does not show an agent's role in any mistake. Or, in other words, which agent made what type of mistake, as for a mistake in a two-player game, there is always a player playing too fast and a player playing too slow. We collected data on which player played too fast. The collected data is shown in Figure 3.5 (n = 1000 repeats for every agent combination). Note that the graph should be read in such a way that every color illustrates an agent type. The size of their column shows the amount of too fast-mistakes against a certain other agent of which the column is stacked on top (or positioned below).

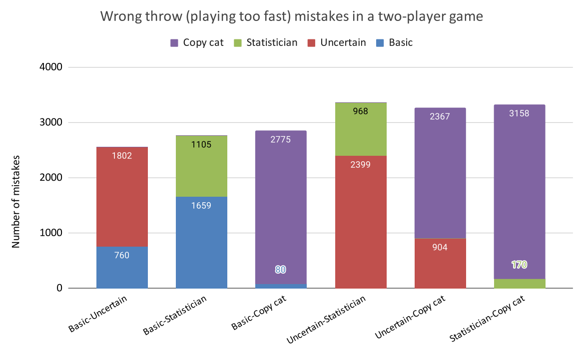

Figure 3.5: Graph showing the times an agent played too fast in two-player games against other agents

A noteworthy finding is the fact that on average the Basic Agent and the Statistician make the least mistakes of playing too fast. The Copy Cat on the other hand is responsible for a lot of the mistakes.

4 Conclusions

The Mind is a versatile game with many hidden elements. Only the visible actions of players are available as information in the context of our model, and after implementing the game and experimenting with multiple possible strategies there are still numerous details to be cleared up. This research was an attempt to uncover some underlying mechanisms in decision-making within The Mind and finding some potentially useful strategies.

4.1 Conclusions shuriken implementation

The effect of the shuriken strategy, based on the difference in cards, did not have much effect on the overall performance measured in win percentage. Even at a smaller scale where the mistakes per game were assessed, little to no variation was found. In order to reach optimal performance of the shuriken card, the shuriken must be played as often as possible, while also keeping the number of mistakes while playing in the shuriken-phase as low as possible. Based on these criteria, a standardized score was constructed. Both lower- and upper thresholds were shown to have an effect on the standardized score, with the lower threshold seemingly having a greater impact. The results also seem to show that higher thresholds more often than not result in a higher scores, which is not consistent with the hypothesis on which the shuriken strategy was based. A potential explanation of this result is the fact that a higher difference in cards will reduce the effective time the players are in the shuriken-phase and therefore also inadvertently lead to fewer cards being played within that time frame. Whether this is the case or not, the results give an indication that a simple implementation of a basic principle behind playing the shuriken card does not sufficiently cover the effects of a shuriken in real life. When playing in real life, the exchange has the potential to be much more nuanced, and therefore be very challenging to entirely implement in an agent-based model such as this.

4.2 Conclusions strategy implementations

Evaluating the different agents showed that both the Statistican and the Basic Agent were most successful in all categories. However, the Basic Agent generally outperformed the Statistician in both a uniform group of agents and in a two-player game with another agent. Whereas the Statistician made the least amount of 'wrong throw' mistakes, even against the Basic Agent. During trial runs, it became clear that the implementation of the Mathematician strategy is not representative for a valid real life strategy as it performed particularly poorly. Furthermore Experiment 3 (Section 3.3) shows that the Uncertain One performs worst in a homogeneous group of agents. This could very well be the result of the high level of uncertainty and thus randomness involved with this strategy. A remarkable observation regarding the Copy Cat is demonstrated in Experiments 3 and 4. Experiment 3 shows that in a uniform group of agents, the Copy Cat performs adequately. Whereas Experiment 4a shows that, in two player games with other agents, it performs below average. Additionally, Experiment 4b shows that the Copy Cat makes an excessive amount of playing too fast-mistakes compared to all other strategies. This seems to be an indication that the adjustment strategy of the Copy Cat is somewhat unbalanced, where the P-modification for playing faster (Equation 2.2) over-adjusts compared to the P-modification for playing slower (Equation 2.1).

4.3 Future research and implications

Multiple elements of The Mind were random for this research to allow for generalisation of the results. Because of this choice, over-generalisation might have occurred. The performances might be very different for games with two agents, than the games with three or four agents. These elements, like player count or levels, also present possibilities. The behaviour of agents can be dependent on the number of agents. Finding an equilibrium could be very different or take more time in a game with two different agents compared to a game with four of the same agents. The Mind only allows for a few mistakes until the game is lost, which leaves little possibilities for the agents to adjust their strategy.

The agent strategies presented in this paper may represent a diverse player population. However, the shuriken strategy did not prove accurate. A strategy for this card could save lives, and effectively improve the win percentage. This element of the game is yet to be explored further, and other than the difference in all cards, one could experiment with just one, or a few cards. There are many more possible theories for the decision making process. If, for example, the difference between the first and last card in someone's hands is very high, the players will theoretically spend more time in the shuriken phase (Section 2.3.3), which could affect performance.

Lastly, this project presented an implementation that obeyed to the rules of the real game, which limited the results. For future research, to generate meaningful result it might be worth exploring leaving out or ignoring rules. With many more levels the agents might also reach an equilibrium and perform optimally without mistakes.

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