

## Random vs Random

Stats:

Random P1 win %	45%
Random P2 win %	47%
Draw %	8%
Turns per game	22
First turn advantage	51%

## Minmax vs Random

100 games at depth 5

Minmax P1 win %	92%
Random P2 win %	4%
Draw %	4 %
Turns per game	17
First turn advantage	50%

**Is your AI player better than random chance? Write a paragraph or two explaining why.**

The minmax algorithm works by traversing a decision tree until it reaches a terminal state, or the specified depth is reached. It then backtracks up the decision tree by applying the max or min value of two states until it makes its way back up to the beginning state. The path that it traces is the next move it makes. It then does this until the entire (real) game is over.

## AlphaBeta vs Random

100 games at depth 5

Random P1 win %	94%
Random P2 win %	2%
Draw %	4%
Turns per game	17
First turn advantage	50%

### How long does it take for a single game to run to completion?

For a single game of AlphaBeta at depth 5, it takes ~0.03 seconds to run to completion.

### Are your results for this part different from those for your minimax AI player?

These results are roughly the same as the Minmax evaluation. This is because AlphaBeta isn't a different decision making method, it simply runs faster than Minmax as it disregards less optimal moves immediately. This means that while the evaluation time is much faster, the moves are inevitably the same given the same or similar opponent moves

## AlphaBeta vs Random

100 games at depth 10

Random P1 win %	97%
Random P2 win %	3%
Draw %	0%
Turns per game	17
First turn advantage	53%
Time (s)	

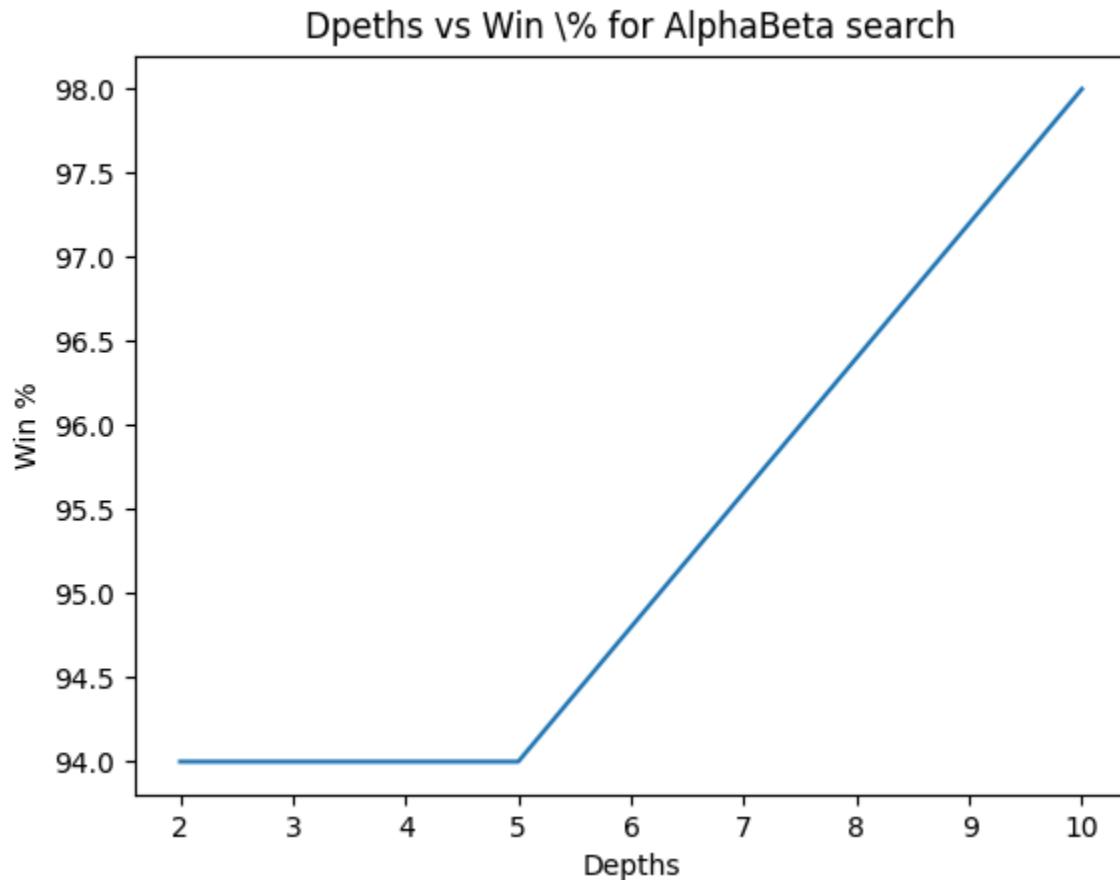
### How long does it take for a single depth 10 AlphaBeta game to run to completion?

At depth 10 a single game of AlphaBeta takes 4 seconds

**How much does the Alpha Beta algorithm speed up the game? Compare your run time for 5 ply minimax against 5 ply Alpha Beta. Project how long Minimax would take to run 10 plies.**

At depth 5, MinMax takes ~0.25 seconds for a single game while a game of AlphaBeta takes ~0.03 so AlphaBeta increases speed by a factor of 8. At depth 10 a single game of Minmax would take ~12 minutes.

**Plot a curve showing the win percentage for a player looking ahead 2 plies, 5 plies and 10 plies**



**As you increase the number of plies, does the AI player win more games?**

As the depth increases, the AI will search deeper into the tree at each stage before selecting a move, this allows it to plan ahead further the deeper the depth.

### **Extra Credit (continuation)**

Implement the continuation rule fully. If you drop your last stone in your own mancala you take another turn. Continue taking additional turns as long as your last stone drops into your mancala.

Show the code changes necessary to make this rule work.

```
class Mancala:
    def __init__(self, pits_per_player=6, stones_per_pit=4, print_output=True, continue_turn=False):
        pass

    def continue_play(self, current_index):
        if self.continue_turn:
            player_mancala = self.p1_mancala_index if self.current_player == 1 else self.p2_mancala_index
            if current_index != player_mancala:
                self.switch_player()
            elif self.print_output:
                if self.current_player == 1:
                    print(f'{color.BLUE}Player {self.current_player} gets another turn!{color.END}')
                else:
                    print(f'{color.RED}Player {self.current_player} gets another turn!{color.END}')
        else:
            self.switch_player()
```

We added an additional argument to the Mancala Game to implement the continuation rule.

**Compare the game results for 10 plies with Alpha Beta with and without the continuation rule.**

The AI which wins most will typically also have a higher number of average turns per game. The optimized AI typically wins even more now since it can prioritize benefitting off the continuation role as opposed to the Random bot.

## No continuation: AlphaBeta vs Random

100 games at depth 10

Random P1 win %	96%
Random P2 win %	3%
Draw %	1%
Turns per game	17
First turn advantage	53%
Time (s)	148.5s

## Continuation: AlphaBeta vs Random

100 games at depth 10

Random P1 win %	98%
Random P2 win %	1%
Draw %	1%
Turns per game	17/15 (P1, P2)
First turn advantage	48%
Time (s)	162.3s

### Explain what causes the win rate to be different.

The continuation rule imposes an even larger ‘skill’ difference between the Random bot vs our optimization as the skill ceiling is raised. The additional mechanic causes different strategies to consider, since you would want to maximize the amount of turns that you take per each round. Therefore, without the continuation rule, it takes shorter time, but with a lesser win rate. With the continuation in