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# Analyzing Games with Varying Number of Players and its Significance using Physics in Mind



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## Abstract

Online multiplayer games have been on the rise in the recent years due to the immense reach and accessibility of the internet all over the world. The online multiplayer trend has been so popular that even notable single-player titles like Red Dead Redemption has begun to add multiplayer modes into their game to satisfy the needs of their customers. Fortnite and PlayerUnknown's Battleground have shaken the world with their enormous player count of over 350 million unique players and a total revenue of over \$1 billion despite having a Free-to-Play business model. Multiplayer Online Battle Arena (MOBA) games have shown us that video games can be as intense and competitive as real sports, boasting a prize of over \$15 million for coming out on top as the best team in the world. In this thesis, we will be looking into the reasons why these online multiplayer games have been so popular over the years by focusing on the number of players chosen in the games. Almost every popular MOBA game has a 5vs5 format as the standard mode for competitions, with similar map layout of 3 lanes. We are interested to see why 5 has been the magic number for MOBA games as well as looking at the player elimination mechanism of battle royale games. A comparison between real sports will also be made by looking into soccer and basketball with its two popular game formats. We anticipate that the numbers chosen for all the games have their own reasons, and feel that having more players make the game more interesting as well as stochastic as it will be much harder to predict the outcome of the games.

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During the two years, I have returned to Malaysia during the Spring break of 2020. However, due to the spread of COVID19, I was not able to return to JAIST until October 2020. I was stuck in Malaysia for 6 months, and this has caused several troubles. I would like to thank the International Student Section for helping me with a ton of paper works and helping me arrange my return back to JAIST. Without them, I am not sure where I might be today.

Not to forget my family and friends who have greatly assisted me throughout these two years, be it physically or mentally. My family have been there my entire life to support me on anything I am doing, despite being faraway at the moment. My lab member also have been a huge source of guidance in both research and life as we often discuss various thing among each other. Each week, we have an online lab meeting where each member will present their current progress to get some feedback from the lab members and our supervisors. During this meeting session, I have received countless feedback and suggestions that helped me improve my understanding in this field.

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# Chapter 1

## Introduction

### 1.1 Background

Video games that are released today can often be divided into two categories: single player and multiplayer games. Both games requires a totally different approach in terms of game design, where single player games create immersive worlds for the player to enjoy on their own while multiplayer games focuses on social interaction among other players [9]. As social interactions in multiplayer games are often unpredictable and random due to the emergence of social rules, it is in turn extra stimulating to the players [10]. However, having too much player could ruin the gaming experience as the world might be too crowded and makes it less memorable. For example, Ramadhan et al. analyzed the card game UNO using game refinement theory and found that the ideal number of player setting is 4 players despite the game suggesting up to 10 player [11].

### 1.2 Research Questions and Objectives

Soccer is one of the most popular sports that has been played for over two thousand years, and it has constantly evolved with the flow of time. Starting 1870, the rules for soccer has been changed, where the most important change is that players are set to 11, where one of them is the goalkeeper [12]. Before that, the number of players usually varied between 15 to 21 players in a team. The reason for this number being set to 11 is unclear, but some say its because 20 players are just nice to cover the entire field, and since each team has one goal keeper, it was decided that each team has 11 players [13].

Similarly, Multiplayer online battle arena (MOBA) games also have fixed format where many developers tend to follow. Almost every MOBA that exists today consists of 5 players on each side, where they play on a virtual map consisting of two bases on opposites joined by 3 lanes. The goal of the game is to push through the lanes and destroy the opponent's base to claim victory while also defending allied structures from being taken [14].

In this research, I would like to compare between games which have different modes or format with varying number of players to see if the numbers set in the rules have reasons behind it. For example, soccer is more popular than futsal, where they have 11 and 5 players on a team respectively. By analyzing these game modes using physics in mind, we can explain the reasons why one of the modes is more popular than the other and is chosen as the standard set of rules. Using the findings from the research, we can determine the suitable number of players for a game to maximize its enjoyment and competitiveness.

I intend to reconfirm the conjectures made by our previous paper where we conjectured that increasing the number of players increases the stochasticity of the game while reducing the number of players made the game more skill based [15]. To achieve this, we will be looking into the battle royale genre, which focuses on eliminating players as the game progresses, which reduces the players until there is only one player left. By making comparisons for games of various genres, it would be possible to make a more accurate conclusion to relate number of players to the excitement of the game.

### 1.3 Structure of Thesis

This thesis is divided into 6 chapters. The first chapter will be the introduction to the research, where the main research question and objectives are discussed. In Chapter 2, the fundamental ideas behind this research will be reviewed, alongside some background on the games which will be used to analyse in the later chapters. We will be looking into three areas: MOBA games, Battle royale games and team-based sports games. Hence, Chapter 3 will consist of the findings and analysis on MOBA games; while Chapter 4 will consist of the finding and analysis on battle royale games; and Chapter 5 will consist of the finding and analysis from team-based sport games. Finally, conclusions will be made in Chapter 6 to conclude this thesis.

# Chapter 2

## Literature Review

### 2.1 Chapter Introduction

Before starting a research on any topic, it is necessary to do a review on current and past works done by other researchers in the field to obtain necessary information and knowledge that can be applied to make any new work done to have a high credibility as well as accuracy. In order to do that, literature review is done to better understand the concepts and mechanisms that will be used in the new work as well as to ensure that the research adds something novel to the existing works. In this chapter, we will first look at some example of multiplayer games and the popular genres. Next, we will look into game refinement theory and its application to various games. Finally, we will look into motion in mind to better understand the concept and make a brief conclusion in the end.

### 2.2 Multiplayer games

There is often a debate on which types of game is more popular, either single player games or multiplayer games. Each format of games have their own benefits to them. Single player games create immersive worlds for the player to enjoy on their own at their own pace, allowing the player to forge their own experience. Multiplayer games on the other hand allows social interaction among other players, sharing the world with another individual as well as allowing cooperation or competition to drive the game forward [9]. A research by Wehbe and Nacke [16] found that players received higher amount of pleasure and perceived arousal in multiplayer games more than in single player game. Multiplayer games with friends also was found to

be more engaging than the same game with an artificial computer controlled player [17]. Hence, a multiplayer setting for games is more preferred in order to increase the player's retention and engagement in the long run. However, the number of players required to maximise the enjoyment of the player in a multiplayer game is relatively unknown. It was previously conjectured that more players in a game increases the stochastic aspect of the game, as it makes the outcome of the game more unpredictable [15]. Conversely, having fewer players makes the game more skill based and challenging. In this research, we will look into a few genre of games with multiple number of players to establish a link between the number of players and the enjoyment of the game.

### 2.2.1 MOBA Games

Multiplayer online battle arena (MOBA) is a genre of game which involves two teams fighting on a battle field aided by computer controlled units and defensive structures, where the main goal of the game is to destroy the enemy's structures. MOBA games are often confused with real-time strategy (RTS) games, which was the true origins of the genre. The main difference between MOBA and RTS games is that players usually only control one unit in MOBA and are not required to construct buildings, while in RTS games, players can control multiple units and are tasked to construct bases using resources that they harvest or mine from the game [18]. RTS games require quick reactions and are often consisting of fast-paced actions, making it difficult even for AI's to master it [19]. Some examples of popular RTS games are Starcraft and Warcraft, both being released by Blizzard Entertainment.

The first major breakout for the MOBA genre is from a custom map created on Starcraft titled Aeon of Strife [20]. Starcraft is developed by Blizzard Entertainment and in 1998, they released the game alongside StarEdit, a game editing tool that allowed anyone to create their own custom maps for the game. In 2003, Blizzard released Warcraft III which also included a game editor like found in Starcraft. Several developers tried to recreate Aeon of Strife on the newer engine in Warcraft III, which led to the birth of Defense of the Ancients, often abbreviated as Dota. Dota was worked on by multiple developers originally, where each one had their own unique character. Later, a modder named Guinsoo merged the various versions of Dota into one, called Dota Allstars. Guinsoo's version of Dota became the dominant custom map in Warcraft III, steadily increasing in popularity. By 2005, the command was passed to Icefrog, one of the lead programmer and developer in the scene at the time. With his talents in balancing the game and leadership, he ensured that the

game is updated regularly. 2006 marked the year where the competitive scene for Dota grew rapidly across the globe [21].

The popularity of Dota continued to rise, until it reached the stage where corporations looked to incorporate the game mechanics as their own. In the late 2009, Riot Games released League of Legends, a MOBA game that was hugely inspired by Dota. League of Legends had a whole new batch of characters with new items, albeit having similar map design as Dota. Certain advanced mechanics from Dota was removed to lower the complexity the game [20], subsequently making it easier for newer players to pick up the game. League of Legends boasts a total of over 150 million registered players, with over 117 million of them being active players [22]. The game had a Free-to-play (F2P) business model [23], which emphasized on the sales of skins that change the appearance of the player. These skins do not provide any competitive advantages to the player and only serves as an aesthetic value. Despite this, they made a revenue of over \$1.75 billion in 2020, proving that F2P model is the best way to monetize your game for long term profit [24].

In 2011, Valve announced their sequel to Dota, titled simply as Dota 2. In order to promote the game, Valve organised The International, a renowned tournament where teams from all over the world compete to win a prize of \$1 million [25], which was unheard of at the time. Many professional players thought that this was a joke, and no one took it seriously for a long time until the tournament was held during the year where they unveiled the game to the public. Similar to Riot Games, Valve decided to follow the same F2P business model for Dota 2, by selling skins and other in-game cosmetic items which do not provide any competitive edge or advantage. As of 2013, Valve introduced a crowd-funding method for the prize pool for The International to allow fans to contribute to their favourite teams called the compendium or battle pass [26]. For every dollar spent, 25% of it will be contributed towards the prize pool for the tournament. This form of monetization method continued throughout the years and proved to be a success as they managed to raise the prize pool of The International 2020 to \$40,018,195 [27], which is the highest prize pool ever for e-sports. The player base for Dota 2 is not as large as League of Legends, as it only has an average of over 400,000 active players monthly, with an all-time peak of almost 1.3 million concurrent players [28].

Following the success story from Riot Games and Valve, various other company sought out to develop their own renditions of the game. Many MOBA games popped up over the years, notable ones are Heroes of the Storm, Heroes of Newerth and Smite [20]. Although these games were not as popular as Dota 2 or League of Legends,

they managed to hold on to their player base by releasing various updates and game modes to ensure a fresh experience for their players. With the ever-improving smartphone industry, MOBA games have been successfully ported over to mobile devices. Mobile Legends, Vainglory and Arena of Kings are some of the popular mobile games in this genre [29, 30]. These games were further simplified to ensure that the duration of the game is not too long as games in Dota 2 or League of Legends can range between 20 to 40 minutes.

Throughout all the MOBA games that has emerged, almost all of them consists of 10 players, where 5 players are placed on each side of the map with the goal of destroying the enemy's base. Somehow, this formula for MOBA games has not changed over the years, despite the game being published across various platforms. It is interesting to find out the reason behind choosing 5 players on each side, despite being able to place more players with the technology available today.

### 2.2.2 Battle Royale Games

Battle royale genre games are relatively new, with the major breakout games being released on 2016. Battle royale is a game genre where a huge number of players are loaded into the game, and players are gradually being eliminated until there is only one player remaining, who will be crowned the winner. This genre was hugely inspired by the Japanese film titled "Battle Royal", which featured a last-man-standing competition in the movie [31]. The genre rose in popularity due to the launch of PlayerUnknown's Battlegrounds (PUBG) and Fortnite in 2016. Both of these games had an insanely huge player base, with over 350 million unique players and a total revenue of over \$1.1 billion over the past few years [32]. The huge numbers for PUBG and Fortnite can be explained due to its availability on all platforms, even on smartphones, making it one of the most accessible games [33].

The battle royale genre is somehow really popular among children. It is highly possible that the genre is highly popular among kids due to the social experiences from the interactions in game as well as with content creators on YouTube or Twitch [34]. The monetization of Fortnite is F2P, where players can purchase various skins and emotes to customize their characters. The skins do not provide any advantage to the player except for looking unique. In PUBG, the PC version requires players to purchase the game before being able to play, where the game is priced at \$29.99. PUBG also have in-game purchases like skins to further receive revenue. This would explain why Fortnite is more popular than PUBG among children, as the startup fees of \$29.99 might be too high for a child, compared to the \$0 of Fortnite. However,

from another research, it was found that an average Fortnite player spend about \$102.42 on in-game purchases [35]. On average, they spent about triple the price of PUBG eventhough the game is completely free. PUBG later released a mobile version of the game, and made this version have a F2P business model. To no one's surprise, PUBG mobile performed better than the PC version of PUBG, with multiple PUBG mobile tournaments being held worldwide [36].

The concept of gradually reducing players by elimination is not entirely new, but has already existed since long ago. A great example of a simple game with this mechanism is the game of Musical Chairs. At the beginning, there will be a lot of players with a number of chairs. As the game continues, the number of chairs will gradually be reduced which in turn reduces the number of players who will proceed to the next round. In the final round, there will be only one chair left, and the player that survives will be the winner. This concept is similar to those in battle royale games. The game starts with a huge number of players, and the players will be eliminated gradually until there is only one person left. In the case of Fortnite and PUBG, the size of the map will be gradually shrunk, ensuring that players will converge towards a point in the end. This makes it impossible for players to remain stationary in one place and win by luck. This random factor might be the reason why the player retention for battle royale games are high, as the game outcome will always be unique.

### 2.2.3 Team Based Sports Games

Traditional sports games have been around for a long time, with its origins from as early as 776BC with the first Olympic Games [37]. Sports during the ancient times are often used as training grounds for wars or to improve hunting skills. The Greeks then invented sports as we know today with the first Olympic Games, introducing sports like chariot racing and javelin throwing, where it was continually evolved over the centuries to became what we know today as sports.

Sports is often said to have positive implications towards health as it ensures the physical activeness [38]. There are also many other secondary benefits from being active in sports, such as psychological developments, self development and the reduction of alcohol. However, several negative implications were also outline, notably risk of injuries, eating disorders, mental health deterioration and burnout [38]. These side effects were often found in professional athletes as a result of the intense training required to remain in shape.



Despite this, sport has been one of the staple forms of entertainment throughout the years, attracting huge audience for major sport events like FIFA and the Olympics. The main contributing factor to the popularity of sports has always been the suspense factor as well as the uncertainty [39]. The suspense can in turn create excitement as well as anxiety among viewers, making the viewers more invested to the game. The uncertainty of sport matches made it possible for the betting industry to thrive as often times the outcome of the game is unpredictable. The competitiveness of sports can then be measured using the likelihood of an upset, where the underdog managed to be victorious [40].

Some of the most popular sports games today consist of teams, such as soccer, cricket, hockey and basketball. Each team consists of multiple players, where some are on-field while the rest are off-field as substitutes for the players on-field. The number of players on field are often fixed according to the rules of the sport, making it interesting to see why the number was chosen in the first place.

By comparing traditional sports with e-sports, we hope to see if both form of sports share similarities which led to their massive popularity. Researchers predicted that the viewership of e-sports will continue to increase and break the 300 million mark in 2023 as it has shown a substantial increase in viewership as of 2018 [41].

## 2.3 Game Refinement Theory

Game Refinement Theory is a theory which was proposed by Iida et al. [42], and it focuses on the sophistication and the uncertainty of the outcome of a game which in turn increases the attractiveness of a game. This theory is not used to calculate winning strategies but is used to see the quality of the game and the amount of entertainment it can provide. As the measure of game refinement is derived from the game progress model, the subsections below will describe about the game progress model and the applications of game refinement theory in various games.

### 2.3.1 Game Progress Model

The game progress is twofold, where one is the game speed or scoring rate while the other is the game information progress throughout the game [42]. Game information progress represents the degree of certainty of the game's results in time or number of steps. If the game information progress is known, the game progress  $x(t)$  at the

end of the game can be represented as a linear function of time  $t$  with  $0 \leq t \leq t_k$  and  $0 \leq x(t) \leq x(t_k)$  as shown in Eq.(2.1).

$$x(t) = \frac{x(t_k)}{t_k}t \quad (2.1)$$

However, the game information progress given by Eq.(2.1) is usually unknown during the in-game phase. Hence, the game information progress is not linear, but can be reasonably assumed to be exponential [42]. This is because the game outcome is uncertain until the very end of many games. Hence, the realistic model of game information progress is given by Eq.(2.2).

$$x(t) = x(t_k) \left( \frac{t}{t_k} \right)^n \quad (2.2)$$

Assuming that the value from Eq.(2.2) represents displacement of information throughout the game, we can then obtain the acceleration of the information by then deriving it twice [42]. Solving at  $t = t_k$ , we obtain Eq.(2.3).

$$x''(t_k) = \frac{x(t_k)}{(t_k)^n} t^{n-2} n(n-1) \Big|_{t=t_k} = \frac{x(t_k)}{(t_k)^2} n(n-1) \quad (2.3)$$

It is assumed in the current model that game information progress in any type of game is encoded and transported in our brains. We do not know yet about the physics of information in the brain, but it is likely that the acceleration of information progress is subject to the forces and laws of physics [42]. Therefore, we expect that a larger value of  $\frac{x(t_k)}{(t_k)^2}$ , the more exciting the game becomes due to the uncertainty of the game outcome. Thus, we use its root square  $\frac{\sqrt{x(t_k)}}{t_k}$ , as a game refinement (GR) measure for other games under consideration as shown in Eq.(2.4).

$$GR = \frac{\sqrt{x(t_k)}}{t_k} \quad (2.4)$$

### 2.3.2 Application of Game Refinement Theory on Games

To find the GR measure for various games, we first need to find the game progress of the game in question. In board games, the game progress can be illustrated as the decision tree for each step or move made. At each depth, one of the possible choice of move will progress the game towards the next depth [42]. Hence, the game progress model can be described as in Eq.(2.5). By deriving Eq.(2.5) twice, we then

can get obtain the GR measure for board games to be  $\frac{\sqrt{B}}{D}$ , where B and D is the branching factor and the depth of the game respectively.

$$x(t) = B \left( \frac{t}{D} \right)^n \quad (2.5)$$

In non board game scenarios, it is difficult to measure the branching factor or the depth of the game. Hence, to calculate the game progress of these game, we can use the score of the game as it represents the game's progress over time [43]. The game progress model for these score based game can be represented as in Eq.(2.6), where G and T represents the average score and the total score attempts respectively. By deriving Eq. (2.6) twice, we then can get obtain the GR measure for score based games to be  $\frac{\sqrt{G}}{T}$ .

$$x(t) = G \left( \frac{t}{T} \right)^n \quad (2.6)$$

We can now use the GR measure to evaluate various games or even sports. Table 2.1 shows some of the GR values for variants of boardgames and scoring sports games [42, 43]. We can see that the GR values lie between a zone value of 0.07 to 0.08. This zone value denotes that the game experience is ideal and provides a sophisticated game with a great balance of skill and chance. A game that lies in this zone is concluded to provide comfort in our mind [44].

Table 2.1 GR value of various games

<i>Game</i>	$x(t_k)$	$t_k$	GR	$v$	$m$	$\vec{p}$	$E_p$
Chess	35	80	0.074	0.22	0.78	0.17	0.076
Shogi	80	115	0.078	0.35	0.65	0.23	0.159
Go	250	208	0.076	0.60	0.40	0.24	0.288
Basketball	36.38	82.01	0.073	0.44	0.56	0.25	0.217
Soccer	2.64	22	0.073	0.12	0.78	0.09	0.022
Badminton	46.34	79.34	0.086	0.58	0.42	0.24	0.283
Table Tennis	54.86	96.47	0.077	0.57	0.43	0.25	0.279

GR measure is also used to measure the entertainment value in various non-game context activities such as evaluating gamification elements in hotel loyalty programs such as points or tiers systems [45], educational applications like Duolingo [46], and even in-game purchases in video game like Dota 2 [26].

## 2.4 Motion in Mind

it is likely that the acceleration of information progress in games are subject to the forces and laws of physics. As the game progress model allows us to calculate the acceleration of information, we could then incorporate it to evaluate forces, momentum as well as energy in games to allow us to better understand the physics in our mind.

### 2.4.1 Zero-sum Games

A zero-sum game is a game theory which can be easily explained in a two-person game of equal skill levels. The theory assumes that any advantage gained by the decisions made by one side results to an equal loss by the opposing side [47]. Any gains from one player always comes at the loss of the other player. We can assume that all players would make a move that incorporates strategies to maximise the benefits for themselves while reducing the loss from the other player's move. Cooperation among players may exist in games such as in team-based games, but in most cases, non-cooperation in games are more attractive as it involves a more intense competition between players [48].

A stronger player has a higher skill to solve uncertainty in a game, implying that the stronger the player, the less the uncertainty they face in a game. Hence, the magnitude of challenge that a player faces during the game can be interpreted as mass  $m$ . According to the game progress model, the velocity  $v$  has an opposing relationship to  $m$ , where  $v$  generally represents the rate of solving uncertainty while  $m$  represents the difficulty of solving such uncertainty [49]. Using the concept of zero-sum game, we can evaluate  $m$  as  $m = 1 - v$ .

### 2.4.2 $m$ -dynamics

Often times, the  $m$  and  $v$  in the game does not stay constant throughout the game, but fluctuates up or down making the game progress dynamically. The importance of the dynamic  $v$  has been explained in a research on roller coasters by Zhang et al. [50], where they focused on the evolution of roller coasters from 1976 to 2016. The roller coaster rides have evolved from focusing purely on thrill into focusing on an exciting ride experience which was observed from the potential energy, momentum, and force of the rides. According to their findings, frequent fluctuating measures are often related to excitement levels, as the changes in acceleration (jerk) contributes to the

"surprise" factor of the ride. Too much jerk makes the user feel overwhelmed, while too little might make the user feel bored. As jerk is proportional to  $v$ , the changes of velocity are considered to induce the feeling of thrill, especially in sophisticated games [49].

### 2.4.3 Application of Motion in Mind on Games

The velocity  $v$  can be described as the rate of solving the game, or also the scoring rate in the game. In board games, the scoring rate can be approximated as in Eq. (2.7) where  $B$  and  $D$  represents the average number of possible moves and game length respectively. In scoring sports games, the  $v$  can be approximated as in Eq. (2.8), where  $G$  and  $T$  represents the total number of goals and shoot attempts per game respectively [49].

$$v \approx \frac{1}{2} \frac{B}{D} \quad (2.7)$$

$$v \approx \frac{G}{T} \quad (2.8)$$

Now that we have the  $v$ , we can obtain the  $m$  using  $m = 1 - v$ . With both mass and velocity, we can then evaluate the various physical formulations that have been established around the motions of an object, such as force, momentum, and potential energy. Table 2.2 below shows the analogical connection between the physics model and the game progress model [49].

Table 2.2 Analogical link between game refinement theory and physics

<i>Notation</i>	<i>Physics</i>	<i>Notation</i>	<i>Game</i>
$x$	Displacement	$y$	Solved uncertainty
$t$	Time	$t$	Total score or game length
$v$	Velocity	$v$	Winning/Scoring rate
$m$	Mass	$m$	Difficulty/Challenge
$g$	Gravitational Acceleration	$a$	Acceleration in mind
$\vec{p}$	Momentum	$\vec{p}$	Momentum of game
$U$	Potential energy	$E_p$	Potential energy in game

Both momentum and potential energy has been defined by Iida et al. in [49]. The momentum in game has been defined by as  $\vec{p} = mv$ , where  $m$  and  $v$  is the mass and velocity respectively. By solving  $\vec{p} = m(1 - m)$ , we can observe that the maximum momentum can be achieved if  $m = 0.5$ . Momentum in game is directly proportional

to the difficulty of the game and the scoring rate in the game. Potential energy on the other hand is defined by  $E_p = 2mv^2$ , where  $m$  and  $v$  is the mass and velocity respectively. Table 2.1 shows the motion in mind values for various board games and sports. Figure 2.1 shows the values of momentum and potential energy in mind across values of  $m$  [49].

$$\vec{p}_1 = mv \quad (2.9)$$

$$E_p = 2mv^2 \quad (2.10)$$

Khalid et al. conjectured that potential energy  $E_p$  is transformed into momentum in games and momentum in mind [51]. Using the Law of Conservation,  $E_p = \vec{p}_1 + \vec{p}_2$ , where  $\vec{p}_1$  and  $\vec{p}_2$  are momentum in game and momentum in mind respectively. By applying Eq.(2.9) and Eq.(2.10), Eq.(2.11) can be obtained which is further derived once to obtain Eq.(2.12). By solving Eq.(2.12), the value of  $m$  can be defined as  $m = \frac{3 \pm \sqrt{3}}{6}$ . At  $m \approx 0.79$  denotes that the game is highly competitive (high excitement in competitive games) while  $m \approx 0.21$  denotes a zone where the game is easy to win or play (strongly engaging or addictive) [51]. Hence, both these zones are notably important in evaluating the engagement of games both objectively and subjectively.

$$\vec{p}_2 = E_p - \vec{p}_1 = 2m(1 - m)^2 - m(1 - m) = 2m^3 - 3m^2 + m \quad (2.11)$$

$$\vec{p}_2' = 6m^2 - 6m \quad (2.12)$$

From Eq.(2.11), the  $v_2$  can be evaluated as in Eq.(2.13), which is the velocity of information in mind. By deriving Eq.(2.13) once, Eq.(2.14) is obtained, which is the acceleration in mind. Applying  $F = ma$ , the force in mind  $F_2$  is obtained as shown in 2.15.

$$v_2 = 2m^2 - 3m + 1 \quad (2.13)$$

$$v_2' = 4m - 3 \quad (2.14)$$

$$F_2 = m(4m - 3) = 4m^2 - 3m \quad (2.15)$$

Force in mind indicates the player's ability to move in the game or the player's strength or skills in general [49]. Figure 2.1 shows the force in mind over values of  $m$ . It can be observed that the force moves from negative towards positive as the  $m$  increases. A positive force corresponds to challenge experienced by players when playing the game (force exerted by the game towards the player) [49]. The negative peak of  $F_2$  at  $m \approx 0.38$  implies that the game pushes the player in order to allow the player to acquire the skills or ability necessary to move the game [51].

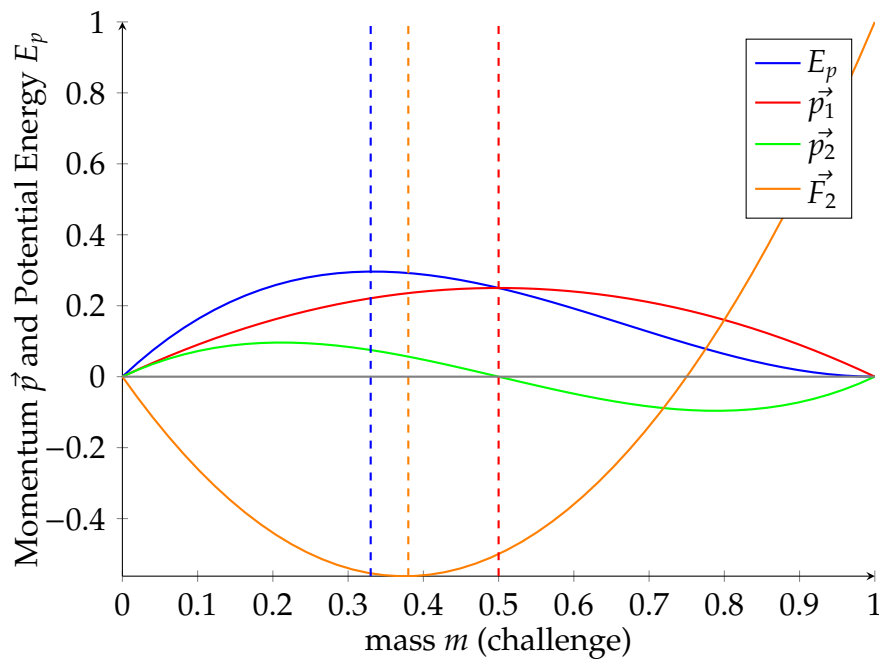


Fig. 2.1 Momentum and Potential Energy in mind across values of  $m$

## 2.5 Chapter Conclusion

As a summary, we can see that multiplayer games are overwhelmingly popular with major games like Dota 2, League of Legends, Fortnite and PUBG which managed to survive the test of time by maintaining its popularity for years. Soccer and basketball are also some examples of popular sports game which has been played by people all over the world across hundreds of years. In order to find out why these games are popular, certain measures need to be used, such as the GR measure and motion in mind. Both of this theory have been used in various fields so far to analyse the engagement of games and several non-game activities. Hence, using these theories to

analyse certain multiplayer games would help us in understanding the significance of having more players in a game.



# Chapter 3

## Analysis of MOBA Games

### 3.1 Chapter Introduction

Multiplayer online battle arena (MOBA) games have become a staple in gaming genres in the past decade due to the immense popularity of League of Legends and Dota 2. MOBA is considered as the most popular form of e-sports as it has successfully attracted millions of players to the tournaments held annually such as Worlds by Riot Games and The Internationals by Valve Corporation [52][53]. The viewership of e-sports has also been increasing steadily, with a projected amount of 300 million in 2023 [41]. In this chapter, we will look into the top two most popular MOBA game: Dota 2 and League of Legends as well as Smite, a relatively new MOBA game that has been released in 2014.

### 3.2 Structure of MOBA Games

MOBA games often consists of 10 players, where they are divided into two teams of 5 players and each team will be placed in a base on opposite sides of the map. The goal of the game is to destroy the enemy's base by first destroying the defensive structures along the route to the enemy's base. These routes are often called lanes, and there are a total of 3 lanes in the game. The areas in between the lanes are called the jungle, where computer controlled enemies (often called as jungle creeps) reside. These jungle creeps provides players with additional resources and aids them in pushing the lanes and ultimately reach the enemy's base. Figure 3.1 shows the common structure of the map in a MOBA game. Although MOBA games have been developed and revamped multiple times by multiple companies throughout

the years, somehow the map structure remained the same across multiple game with minor modifications.

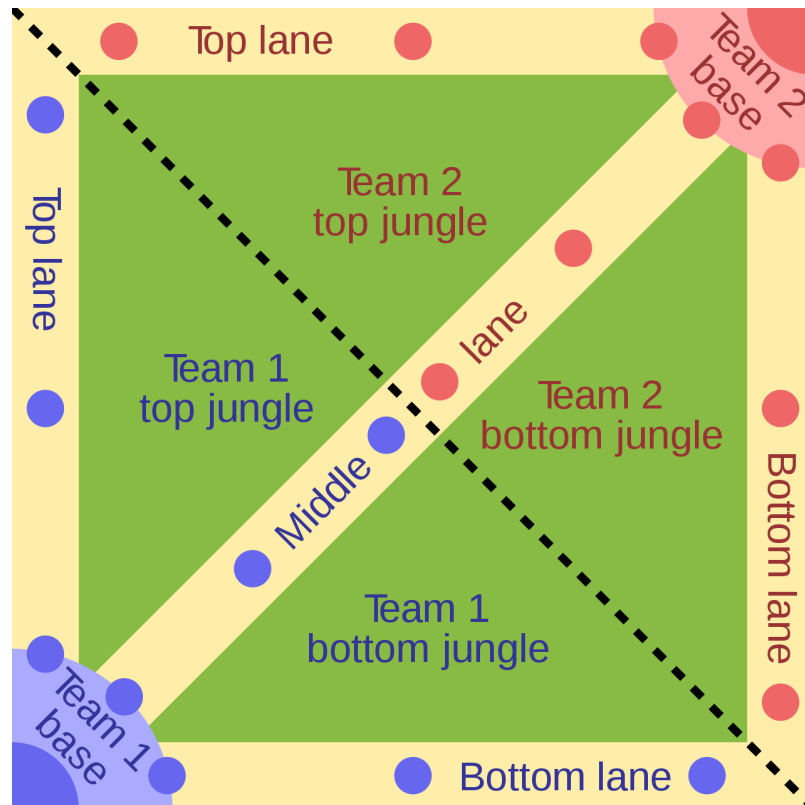


Fig. 3.1 Map Structure in MOBA games, from [1]

In order to keep the game fresh, each MOBA game has a large pool of playable characters, where each character have their own unique skills. Each character have their own strength and weaknesses, making it important to have a certain line-up of characters to gain an advantage over the opponent as well as to cover up the weaknesses of allied characters [54]. In tournaments, players will go through a drafting phase, where they take turns to ban or pick heroes for their respective teams. This drafting phase revolves around decision making based on game strategies, synergies between characters, mastery of the players with the character as well else external trends of the game called the meta-game [55]. With some MOBA games having over 100 different characters to choose from, it creates endless possibilities for hero combinations, making each game a unique experience as no two games progresses in the exactly same manner.

## 3.3 Games Analysed

In this section, we will briefly explain about the games and its available modes to be analysed in the subsequent sections. The games used in this research are Dota 2, League of Legends and Smite, which are three notably popular MOBA games as of 2021.

### 3.3.1 Dota 2

Dota 2 has two competitively viable modes: 5vs5 and 1vs1, with the standard competitive mode consisting of 10 players. The standard mode consisted of 5 players on each team with the goal of pushing through and destroying the opponent's base. The map structure has 3 lanes, just like in Figure 3.1. However, each team has a slight advantage over the other team on a lane. For example, Team 1 has an advantage in the Bottom Lane, but Team 2 has an advantage in the Top Lane. Hence, these lanes are known as the "safe-lane" for the respective teams. Some professional teams have their own preferences for which side to be in, as they might have a higher winning rate on a different side. Therefore, to ensure fairness, competitions usually start with a coin flip, where the winner gets to choose which side they get to play on.

The 1vs1 mode is often called Only Mid, as it played only over the Middle Lane. The goal of the game is to kill the enemy player twice, or to destroy one of the opponent's tower. This ensures that the length of the game is not too long. On average, the game duration for 1vs1 is about 8 minutes, compared to 40 minutes for the 5vs5 mode. 1vs1 mode is often noted as the mode to test the skills of the player as they can only win the game with their own efforts. Hence, it is often used as a form of duel among players to see who is the best.

### 3.3.2 League of Legends

Summoner's Rift is the standard mode in League of Legends. It has the standard structure as most MOBAs: 5 players on each team and 3 lanes. The lanes structure are mirrored and identical for both teams, making it much fairer than in Dota 2. This ensures that no team has an added advantage due to the structure of the map.

League of legends has introduced various modes throughout the years, notably Twisted Treeline, which is a 3vs3 game mode which was played on a map with a single lane. However, Twisted Treeline has been removed from the game in 2019 [56]. Although the mode was one the fan favourites, Riot Games still decided to

remove the mode due to several reasons. Twisted Treeline rewarded players with valuable in-game skins when they won the games; while there also was people who used the game mode to level up their accounts as it was much quicker to enable them to play in Ranked matches [57]. Hence, Riot Games decided to remove the game permanently. Multiple petitions was created by the players, however they were in vain.

### 3.3.3 Smite

Smite's popularity is not on the same level as Dota 2 or League of Legends, but it is still one of the notable games in the MOBA genre. Smite has multiple game modes unlike Dota 2 or League of Legends. Currently, Smite has 6 official modes: Conquest, Joust, Arena, Assault, Clash and Siege. Conquest is the standard mode used for competitions, however this mode is not the most popular mode of the game. Joust mode was the most popular mode in Smite as there were notably more games played over the standard mode. Figure 3.2 shows an overview of the games played over the 8.6 patch.

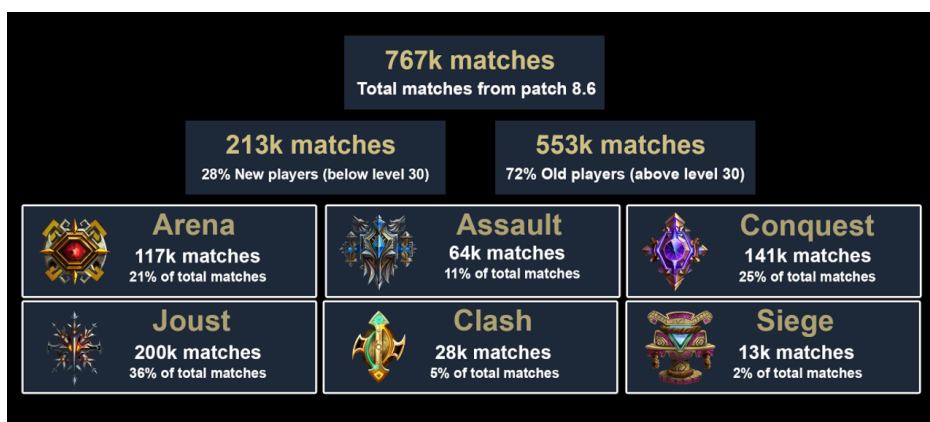


Fig. 3.2 Statistics of Smite games played over patch 8.6, from [2]

The game structures in all 6 modes of Smite are different, which makes it interesting for players to try each of them. Each mode is unique as it has varying number of players, lanes or mechanics overall. This helps to keep the game interesting and fresh to players. Below is a brief explanation of each game mode [58]:

- **Conquest:** The standard competitive mode consisting of 5 players on each team played over the standard map with 3 lanes. The goal of the game is to push and destroy the enemy's base.

- Joust: The most popular mode consisting of only 3 players on each team played over a map with only one lane. The goal of the game is to push and destroy the enemy's base.
- Arena: Consists of 5 players on each team played over a circular map with no lanes. It resembles a battle arena, with the goal of reducing opponents ticket points to 0. Each team start with 500 ticket points and can be reduced by killing enemy heroes or pushing.
- Assault: Consists of 5 players on each team played on a map with only one lane. The goal of the game is to push and destroy the enemy's base.
- Clash: Consists of 5 players on each team played on a map with two lanes. The goal of the game is to push and destroy the enemy's base.
- Siege: Consists of 4 players on each team played on a map with two lanes. The goal of the game is to push and destroy the enemy's base. In this mode, player can gain points to summon a juggernaut to help them push through the enemy's structures.

The developers of Smite are braver than others as they are willing to experiment with the MOBA formula. However, due to underwhelming support for the Clash and Siege modes, the developers have announced that the game modes will be removed and merged into a new mode called Slash [59]. Not much information is known yet for this new game mode, but we can hope that the popularity of this new mode will increase.

### 3.4 Findings and Analysis

In general, MOBA games have one main objective: to destroy the enemy's base. However, this is not as easy of a task as the defensive structures in the base are quite strong compared to the player's character. Players can only get stronger by gaining experience and gold from killing enemy players and units, making it a crucial way to gain an advantage over the enemy. Previous works done in the domain of MOBA (Dota 2) evaluated the  $GR$  using only the kills parameter, where  $GR = \frac{\sqrt{K}}{T}$ , where  $K$  and  $T$  represents average number of kills and the average number of attempts per game, respectively. [45]. However, we feel that to better understand the game, we will need to look at both the gold and experience values as well instead of only the kills.

We propose a weighted-mass concept, where the  $m$  is evaluated for each advantage (kills, gold and experience), and a weighted average is obtained to better evaluate the games. The formulas for  $v$  for kills, gold and experience is expressed in Eq.(3.1), Eq.(3.2) and Eq.(3.3), respectively.

$$v_{kills} \approx \frac{WinnersKills}{TotalKill} \quad (3.1)$$

$$v_{gold} \approx \frac{WinnersGold}{TotalGold} \quad (3.2)$$

$$v_{exp} \approx \frac{WinnersExperience}{TotalExperience} \quad (3.3)$$

Once the velocity of each advantage is obtained, the  $m$  value is obtained by using  $m = 1 - v$ . Weightage can be defined as the importance of one value compared to the others. To calculate the importance of certain advantages, we can simply divide the number of games where the winning team has advantage in that field and divide it by the total games. To calculate weightage of having an advantage in kills in the context of MOBA games, we will divide the number of games where the winning team has a kill advantage with the total games played. This will give us the average importance (or weightage) of that particular aspect throughout the game. Table 3.1 shows an example of weightage calculated for games played in The International 2019 for Dota 2.

Table 3.1 Weightage calculations for Dota 2

	Kills	Gold	Experience
<b>Winner has advantage</b>	374	383	373
<b>Loser has advantage</b>	20	23	27
<b>Draw (no advantage)</b>	12	0	6
<b>Total Games</b>	406	406	406
<b>Weightage</b>	0.921	0.943	0.919

With the weightage of each advantage, we can now obtain the weighted average  $m$  value which takes into account all 3 advantage of kills, gold and experience using the formula in Eq.(3.4).  $w_i$  and  $m_i$  represents the weightage value for each advantage and the mass of each advantage, respectively.

$$m = \frac{\sum_{i=1}^n w_i m_i}{\sum_{i=1}^n w_i} \quad (3.4)$$

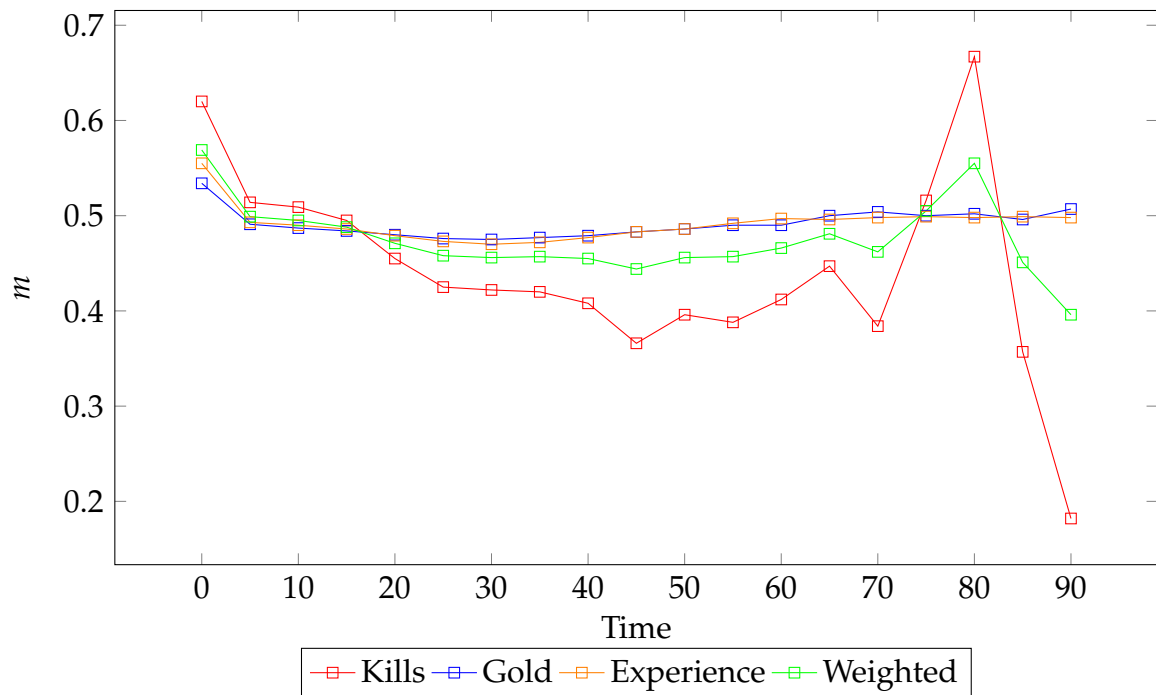


Fig. 3.3 Comparing values of  $m$  throughout a game of Dota2

Figure 3.3 shows the changes of  $m$  throughout the games in The International 2019 tournament for Dota 2. It can be observed that the gold and experience are almost identical and maintains at the zone of  $m = 0.5$ , which signifies that the game is fair in terms of obtaining gold and experience. This can be explained as the main method of obtaining gold and experience in a game of Dota 2 is by killing computer controlled unit (often called creeps). These computer controlled units are much easier to kill compared to player controlled units, making it a reliable way to constantly obtain gold and experience. These creeps also maintain the same difficulty level, such that they do not get stronger over time, making it much easier to kill them in the later stages of the game.

Kills however is more erratic, such that it exists between the ranges of 0.18 to 0.67. The  $m$  value using kills shows that the game is highly competitive at the start, and gradually drops to become fairer and shoots back up during the final few minutes of the game. This is because the game is often decided by the kills made in the 70 to 90 minute range, making the highly tense in these stages. At 90 minutes, the  $m$  drop to an all-time-low of 0.18, showing that the game is often already decided at this point.

By looking at the weighted mass values of  $m$  in Figure 3.3, we can see that the flow is less erratic, and maintains at the zone between 0.4 and 0.6 in contrast to the

erratic flow of  $m$  in kills. We can say that the weighted average helps to tell a better story of the flow of the game, making it less one sided when looking only at the kills.

Table 3.2 Motion in mind values for Dota 2, League of Legends and Smite

Game	Mode	Players	$m$	$v$	$\vec{p}_1$	$E_p$	$\vec{p}_2$	$F_2$	$GR$
Dota 2	Captains Mode	5vs5	0.475	0.525	0.249	0.262	0.012	-0.523	0.070
	Solo Mid	1vs1	0.753	0.247	0.186	0.092	-0.094	0.009	0.011
League of Legends	Summoner's Rift	5vs5	0.402	0.598	0.240	0.288	0.047	-0.560	0.078
	Twisted Treeline	3vs3	0.523	0.477	0.249	0.238	-0.011	-0.475	0.102
Smite	Conquest (Standard)	5vs5	0.440	0.560	0.246	0.276	0.030	-0.546	0.078
	Arena	5vs5	0.471	0.529	0.249	0.264	0.014	-0.526	0.053
	Joust	3vs3	0.392	0.608	0.238	0.290	0.051	-0.561	0.098
	Clash	5vs5	0.447	0.553	0.247	0.273	0.026	-0.542	0.069
	Siege	4vs4	0.435	0.565	0.246	0.278	0.032	-0.548	0.085

Table 3.2 shows the motion of mind values for each modes in the MOBA games that was analysed using the weighted mass concept. The standard mode for each game is listed on the top, followed by its variations.

The standard mode for Dota 2 has an ideal  $GR$  value of 0.07, which is within the sophistication zone, contrasting to the 1vs1 mode which has a very low  $GR$  of 0.011. As previously explained, the 1vs1 mode of Dota 2 is often used as a form of duel among players to see who is the more skilled player as they have to move the game with their own abilities. This can also be observed in the value of  $m$  which also denotes the challenge level in the game, where 1vs1 is clearly more challenging than the standard 5vs5 mode. The momentum in game  $\vec{p}_1$  and potential energy  $E_p$  of the standard mode of Dota 2 is much higher than the 1vs1 mode, making it more engaging and exciting to player when they play the game. The  $\vec{p}_2$  of the standard mode of Dota 2 is much closer to  $\vec{p}_2 = 0$  compared to the 1vs1 mode. When  $\vec{p}_2 = 0$ , it indicates that the game becomes almost like a frequent see-saw game, where it implies the greatest attractiveness of play [51]. This might explain why more players and even spectators prefer the standard 5vs5 mode of Dota 2 as its more enjoyable compared to the 1vs1.

When comparing between the two modes of League of Legends, it can be observed that the Twisted Treeline (3vs3 mode) is shows a much ideal results in terms of motion in mind. The  $m$  value of 3vs3 is much close to the fairness zone and its close to the peak of momentum in game  $\vec{p}_1$ . Despite this, the 3vs3 mode was removed in 2019 due to various non-game related reasons [57]. This mode used to be a fan favourite, showing that the design of the game is not flawed. However, in terms of  $GR$  value, the standard 5vs5 mode is much more ideal as it is located within the



sophisticated zone. This shows that the standard mode has a good balance between skill and chance to remain competitive compared to the 3vs3 mode.

Smite is probably the most interesting of all, as the findings slightly contradict reality. Clash and Siege are two modes which will be discontinued as of 2021 [59], but the motion in mind values are not much different from the standard mode. The  $GR$  values are also not too far from the zone value of 0.07 to 0.08. Based on the comments from Reddit forums by the players, some players mentioned that Siege used to be a casual 5vs5 mode before it was turned to a 4vs4 mode [60]. The popularity of the game also apparently decreased due to the troubles with matchmaking system, where problems like less players and unbalanced player skill levels caused the game to be very one sided and boring. There are currently no official tournaments held with Clash or Siege modes. Using data from official tournaments can help in removing the influence of matchmaking and ensure that most of the games consists of players of equal skills, resulting in a more accurate result. Some players also felt that Clash games often led to stalemates due to the difficulty in pushing as the map is smaller [61]. The defensive structures in these games are also said to be too strong, making the game take too long to end.

Unlike Dota 2 and League of Legends, the most popular mode in Smite is not the standard mode, but the most popular mode is Joust, a 3vs3 game played over a single lane, similar to League of Legend's Twisted Treeline. Joust had the highest  $GR$  value compared to all other modes in Smite, similar to how Twisted Treeline had a much higher  $GR$  value. This shows that the game is very exciting and more stochastic than the standard modes. From the game data collected, Joust had more games which were one sided in terms of kills, where  $v_{kills} = 0.72$ . Despite this, the game still manages to stay at top as the most popular mode, where Smite players can queue for Ranked Joust matches.

The momentum in mind value  $\vec{p}_2$  for Smite's Arena mode is the closest to 0. As previously indicated, games with  $\vec{p}_2 = 0$  show has the highest attractiveness of play as the game is a constant see-saw, making it very unpredictable. Arena also has different goals and implements a ticket mechanism, promoting more active game play, with an average of 57.9 kills per game compared to the standard mode with only 25.6 kills per game. As the game revolves around kills, it becomes very difficult to determine the winner until almost at the very last moments. Each team start with 500 ticket points, and the goal of the game is to reduce the opponent's ticket score to 0 to win. In average, the remaining tickets for the winners from the data collected is

only 29.8, showing that the games are often very close. This confirms that the game is very unpredictable as the lead is often a back and forth like a see-saw.

### 3.5 Chapter Conclusion

MOBA games have a long history of implementing 5 players on a team despite being on various platforms today. By looking at it using motion in mind theories, we can see some cases where the non-standard modes of less than 5 players being more popular like Smite's Joust and League's Twisted Treeline. One of the possible reasoning behind the number 5 for MOBA games might be due to the balancing aspect of the game. Each character has their own strength and weaknesses, making it very important to choose the correct characters for the best synergy [54]. Most synergies require two or more characters, while some additional characters are required to counter the synergy of the opponent, making 5 a suitable number. In 3vs3 modes, often times the games are one sided as there is less room to counter the opponent's strategy, making the game sometimes one-sided like in Smite's Joust. From all the game that was compared, only one of them had an even number for players or the number of lanes, which is Siege. It might not be a coincidence that Siege is the least popular mode, as having odd number of players or lanes are somehow more interesting in of MOBA games.

# Chapter 4

## Analysis of Battle Royale Games

This chapter is an updated and in-depth version of the following publication:

- Sagguneswaraan Thavamuni, Muhammad Nazhif Rizani, Mohd Nor Akmal Khalid, and Hiroyuki Iida (in press). Significance of Player Elimination in Battle Royale Games Popularity. in Asia-Pacific Journal of Information Technology and Multimedia (APJITM).

### 4.1 Chapter Introduction

Battle royale is a relatively new game genre, with the first mainstream breakout being released in 2017. The genre then rose up to popularity, spawning various games that incorporated the battle royale formula to attract more players towards their game. It essentially is a survival game, where players will be slowly eliminated until there is only one person remaining. The concept is relatively simple, but it proves to be quite attractive to younger audience with about 41% of school-aged kids regularly playing battle royale games [62]. In order to determine why this formula is very engaging for younger audiences, we will look into PUBG, Fortnite and Fall Guys, which are three popular battle royale genre games recently.

### 4.2 History of Battle Royale Games

The origin of battle royale games are said to be from movies such as the Japanese film "Battle Royale" and "Hunger Games", where it features survival-game where it involves players being forced to eliminate others until the last man standing. In the gaming media, battle royale's first notable appearance was on a mod for

Arma 2 titled DayZ on 2012. DayZ had the main flaw where the map size is too large that players have infrequent interaction among each other, which called for many other developers to improve the game. One modder named Brendan Greene with an online alias "PlayerUnknown" released his own mod of DayZ with tons of improvement, increasing its popularity until the game developers approached him to design his own standalone battle royale game simply titled PlayerUnknown's Battlegrounds.

Epic Games then released Fortnite in 2017, which had both a survival campaign as well as an online battle royale mode with 100 players. Both PUBG and Fortnite brought the battle royale to the mainstream, where many other developers wanted to incorporate the battle royale concept into their games. For example, franchises like Call of Duty, Battlefield, and even Dota 2 introduced battle royale modes into their game. Just like the MOBA genre, most of the other battle royale game lost their popularity months after the initial release as players returned to PUBG or Fortnite.

## 4.3 Games Analysed

In this section, we will briefly explain about some of the top and uprising games in the battle royale genre in the past years. The games used in this research are PUBG, Fortnite and Fall Guys.

### 4.3.1 PlayerUnknown's Battlegrounds

Player Unknown Battlegrounds (PUBG) is a third-person shooter with up to 100 players at a time, where the goal of the game is to be the last person standing [63]. PUBG was one of the most popular battle royal game when it launched in 2017 and maintained its popularity as one of the top battle royale games today [64][65]. Players can choose to play in several mode: Solos, Duos or Squad where the players will be either alone, in a team of two or four respectively.

At the start of the game, players are loaded to an airplane and flown across the map, where the players can choose when to drop from the plane to land on the map [66]. Once they land, they will have to scavenge the area to find guns and various other items to help them survive. As the map is quite large, to ensure that players will engage with each other, the play area will gradually shrink throughout the game's duration. This is done by using a game concept called "The Circle". This circle shows the new play area (also known as the safe zone) and players will need



Fig. 4.1 Example of The Circle in PUBG, from [3]

to move to the new area as soon as possible. Any players outside the safe area will gradually take damage and will be eliminated if they are there for too long. This ensures that players will engage with other players as they are moving to the new safe areas, helping to avoid stalemates and leaving only one survivor in the end. Figure 4.1 shows an example of the circle in a game of PUBG. The circle shrinks in fixed time intervals throughout the game, but the location of the new circle will be randomized within the current circle, creating an element of chance in the game.

### 4.3.2 Fortnite

Fortnite is another popular third-person shooter battle royale game where players are loaded into a flying bus and dropped via parachutes to an island alongside 99 other players [67]. Each player is only equipped with a pick-axe which can be used to do slight damage to enemy or to collect materials such as wood and metals to help with construction. The main difference between PUBG and Fortnite is that players can construct walls, stairs and various other things to provide offense or defense or even both to the constructor. The ability to build structures make this game unique and fun for players as it adds endless possibilities on how the player can tackle the challenges in a game. Fortnite rose up to popularity on its release and maintained its top spot as the most popular battle royale game with over 350 million unique players [68].



Fig. 4.2 Example of The moving Storm in Fortnite, from [4]

Similar to PUBG, the play area in Fortnite shrinks as the game goes on using game mechanic called “The Storm”. Any player outside of the safe area will constantly take damage until they are eliminated, forcing players to rush to the safe area as soon as it is revealed. However, Fortnite has a mechanic called the moving Storm, where the new circle might be outside of the current play area. Figure 4.2 shows an example of the moving storm. This forces player to move through the Storm and take some damage along the way to the new play area. This makes it necessary for players to collect healing or shielding items to recover the health they lost along the way, making it important for players to scavenge areas or loot from other player who have been eliminated. The moving storm only starts after round 4, which is around the 15 minute mark in the game.

### 4.3.3 Fall Guys

Unlike PUBG and Fortnite, Fall Guys is not a third-person shooter game, but is a more fun take on the battle royale genre. Fall Guys is a multiplayer game where the players have to navigate through mini-games and obstacles, similar to the obstacles in famous shows like "Takeshi's Castle" and "Total Wipeout" [69]. The game starts with 60 players and gradually reduced until there is only one player remaining. In a single round, a maximum of 20 players can be eliminated. Players who do not make it to the finish line of the obstacles in time or those that got the last place in the mini-game will be eliminated. There will be about 4 to 6 rounds in a game, where each round has its own obstacle course which will be selected randomly to ensure



Fig. 4.3 Example of an obstacle course map in Fall Guys, from [5]

the game does not get stale quickly. Figure 4.3 shows an example of an obstacle course in Fall Guys.

## 4.4 Findings and Analysis

Before we evaluate the games using motion in mind, we will first need to define the velocity  $v$  of the game. As we would like to focus on the player elimination factor in the game, we proposed Eq.(4.1). Both PUBG and Fornite will be using this formula to evaluate the  $v$ .

$$v \approx \frac{G}{T} \approx \frac{\text{TotalKillsinRound}}{\text{TotalPlayersinRound}} \quad (4.1)$$

The data for Fall Guys was obtained from a player who recorded his own games of over 500 games [70] as there are no publicly available match data for Fall Guys as of the time of this paper. The player was relatively high skilled, with winning rates of over 90% on opening rounds. In order to calculate the  $v$  based on the data obtained, we will use the formula in Eq.(4.2).

$$v \approx \frac{G}{T} \approx \frac{\text{TotalRoundsQualified}}{\text{TotalRounds}} \quad (4.2)$$

The values of  $v$  are calculated for each round for PUBG, Fortnite and Fall Guys and are tabulated below in Table 4.1, Table 4.2 and Table 4.3 respectively.

Table 4.1 Motion in mind values over each phase in PUBG

Phase	$v$	$m$	$\vec{p}_1$	$E_p$	$\vec{p}_2$	$F_2$	$GR$
1	0.120	0.880	0.106	0.025	-0.080	0.458	0.009
2	0.232	0.768	0.178	0.083	-0.096	0.056	0.014
3	0.379	0.621	0.235	0.178	-0.057	-0.320	0.020
4	0.385	0.615	0.237	0.182	-0.055	-0.332	0.026
5	0.450	0.550	0.247	0.222	-0.025	-0.439	0.036
6	0.388	0.612	0.237	0.184	-0.053	-0.338	0.046
7	0.592	0.408	0.242	0.286	0.044	-0.558	0.078

Table 4.2 Motion in mind values over each phase in Fortnite

Phase	$v$	$m$	$\vec{p}_1$	$E_p$	$\vec{p}_2$	$F_2$	$GR$
1	0.073	0.927	0.068	0.010	-0.051	0.656	0.008
2	0.065	0.935	0.061	0.008	-0.030	0.693	0.008
3	0.039	0.961	0.037	0.003	-0.109	0.811	0.006
4	0.128	0.872	0.112	0.029	-0.011	0.424	0.012
5	0.041	0.959	0.040	0.003	-0.066	0.800	0.007
6	0.075	0.925	0.070	0.011	-0.079	0.645	0.010
7	0.099	0.901	0.089	0.018	-0.062	0.544	0.012
8	0.087	0.913	0.080	0.014	-0.027	0.594	0.012
9	0.043	0.957	0.041	0.003	-0.016	0.794	0.009
10	0.980	0.020	0.020	0.039	0.039	-0.059	0.043

Table 4.3 Motion in mind values over each phase in Fall Guys

Phase	$v$	$m$	$\vec{p}_1$	$E_p$	$\vec{p}_2$	$F_2$	$GR$
1	0.990	0.010	0.010	0.019	0.010	-0.030	0.044
2	0.891	0.109	0.097	0.154	0.057	-0.279	0.042
3	0.864	0.136	0.118	0.175	0.058	-0.334	0.044
4	0.693	0.307	0.213	0.204	-0.008	-0.544	0.043
5	0.550	0.450	0.248	0.150	-0.098	-0.540	0.049
6	0.125	0.875	0.109	0.003	-0.106	0.438	0.125

As expected that the value of  $m$  changes throughout each round, making the challenge factor of the games dynamic. Figure 4.4 shows the  $m$ -dynamics of PUBG,



Fortnite and Fall Guys across each round. The trend for  $m$  of all three games are different. PUBG and Fortnite starts of the game with  $m > 0.8$  in contrast to Fall Guys which start at  $m = 0.01$ . Games with  $m \approx 0.79$  indicates that it is highly competitive (high excitement in competitive games) [51]. Fall Guys only reaches this phase at the final rounds while both PUBG and Fortnite start at the competitive zone. Fortnite maintains ins the zone for almost the whole game and only drops at the final round. This shows that Fortnite is very competitive throughout the whole game and manages to be engaging to the players. The value of  $m$  in PUBG drops across the rounds and stabilises at round 3 at  $m > 0.5$  until the final round. This shows that PUBG starts of very competitive, slowly becomes less challenging but more fair towards the players. Player of PUBG might have a smooth experience in the game as they could feel the progression of themselves in the games. Fall Guys however shows that the game is very easy at the start, but quickly becomes more challenging as they proceed further. This can be seen in our data for Fall Guys as the player has over 90% winning rate in the earlier rounds, but only a 20% winning rate in the final rounds.

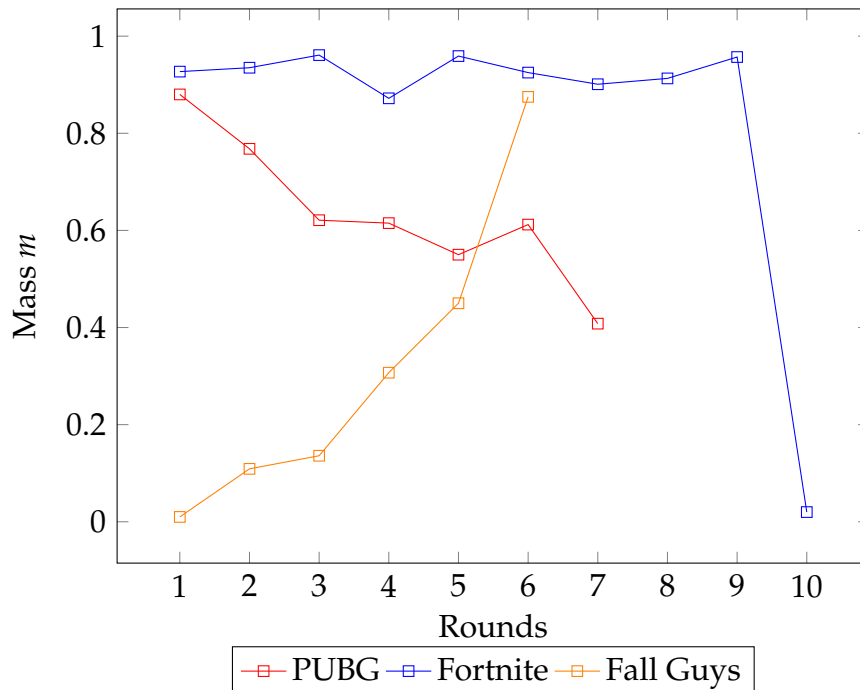


Fig. 4.4  $m$ -dynamics in Battle Royale games

As previously mentioned, Fortnite is more popular among younger audiences and kids in general. By observing the force in mind  $F_2$  of all three games that is shown in Figure 4.5, we can see that Fortnite maintains a positive  $F_2$  for almost

the whole game. A positive force corresponds to challenge experienced by players when playing the game (force exerted by the game towards the player) [49]. This force might be effective in providing thrill and excitement among younger audience, creating a higher impact to them compared to other games which in return causes them to return to Fortnite. The other battle royale games that was analysed shows  $F_2$  decreasing rapidly throughout the game, with the exception of Fall Guys having an increase in the final round. This jump might be because the final round in Fall Guys is simply the most challenging round throughout the game.

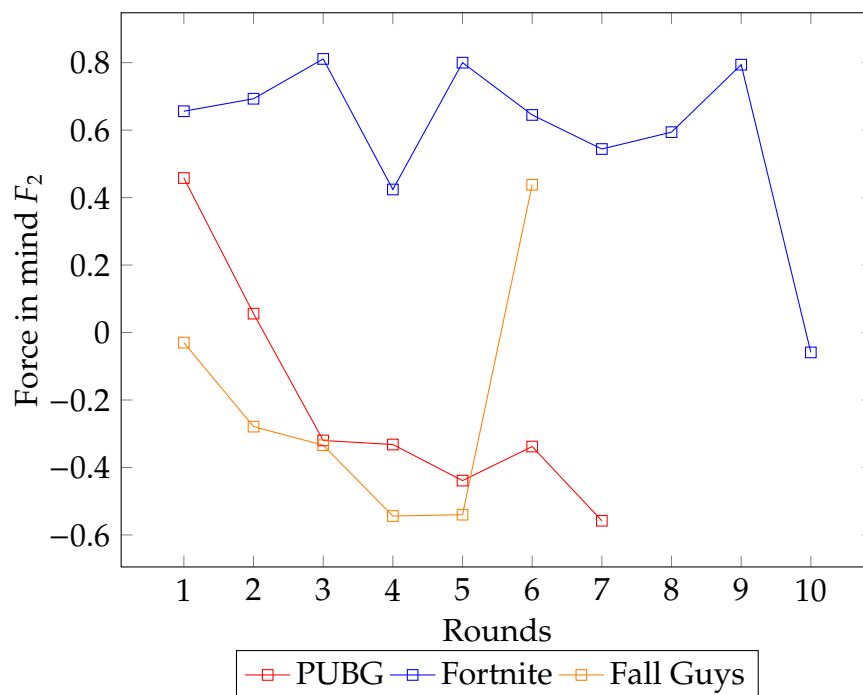


Fig. 4.5  $F_2$  in Battle Royale games

In all three games, players are constantly being eliminated over time until there is only one player in the end. Previously, we have conjectured that games get more deterministic when the game has less players [15]. However, we can see that the  $GR$  values increases throughout the rounds for all three games in Figure 4.6. This shows that the game is getting less deterministic but more stochastic, converse to our previous conjecture. Perhaps the lower number of players in the final rounds make the game less predictable as each player that remains are equally skilled with enough resources to win.

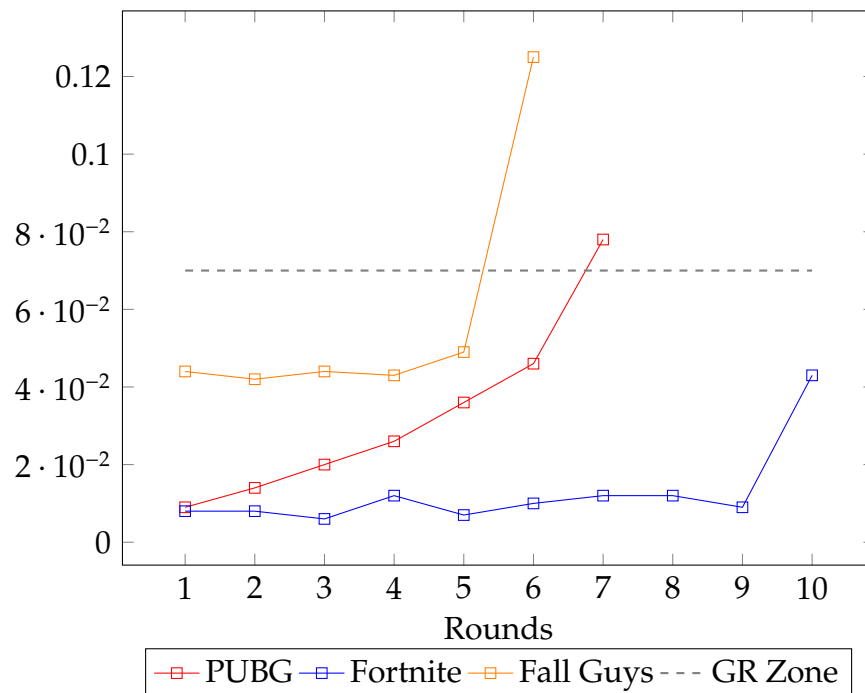


Fig. 4.6 GR in Battle Royale games

## 4.5 Chapter Conclusion

In summary, we can see that the mechanism of eliminating players over time can drastically change the difficulty and challenge in the game. The changes in difficulty is often based on the game itself, as it is difficult to generalise it simply as having lesser player making the game easier or difficult. In PUBG, it can be observed that the game starts out challenging but slowly decreases in difficulty, approaching the  $m = 0.5$  zone. Player can sense the progression as they progress in the game steadily. In the case of Fortnite, the game manages to maintain the difficulty throughout the game, making it more attractive and comfortable to players. This could be an explanation to why the game has a large audience of kids. In Fall Guys, the game is generally easy and gets more challenging as the game progresses, and being the toughest at the end. This might be a common design for most games, however this might not be too appealing as the sudden "jerk" of difficulty is not comfortable.

# Chapter 5

## Analysis of Team Based Sports Games

### 5.1 Chapter Introduction

Sports have been a staple form of competition all over the first since the introduction of the Olympics back in 776BC [37]. Sports games can be classified into a few categories: Solos, Duos or Team based, where it consists on only a single athletes, two, or more respectively. Badminton is an example of a sport which can be classified to both solo and duo as it has singles and doubles matches consisting of only one player or two respectively. Team based sports games often has more fans worldwide and attract a larger traffic which can be seen in the popularity ranking of sports games where the top 3 sports listed are all team based[71]. In this chapter, we will be looking into soccer and basketball as it has 2 popular variations of the game with different number of players to explain how the number of players affect the popularity and enjoyment of the game.

### 5.2 Popularity of Sports Games

Soccer is said to be the world's most popular sport [72], with approximately 4 billion fans worldwide [71], while basketball is not as popular as soccer, but it is notably popular especially in the US.

Soccer (also known as football) is a sport where players can only use their legs to kick the balls into goal posts that are located on opposite sides of the field. The game is played in two halves of 45 minutes, and the winner of the game is decided based on the score in the end of the game. Only the goal keepers are allowed to use their hands to touch the ball. The wide reach of soccer can be seen in the multiple

leagues and tournaments in all corners of the world. Major tournaments like FIFA World Cup and EURO brings together teams from all over the world to compete for the title of the best team in the world.

Basketball on the other hand is slightly opposite to soccer, where players are only allowed to use their hands throughout the game while legs are not allowed. The game is played over four quarters of 12 minutes for a total of 48 minutes. However, there are multiple timeouts allowed throughout the game unlike in soccer. Basketball is more popular in North America due to the National Basketball Association (NBA) league held in the United States. Similar to soccer, FIBA World Cup is held every four years, and it brings together various nations worldwide to crown the best team in the world.

## 5.3 Games Analysed

In this section, we will briefly explain about soccer and basketball, and its different formats for the game.

### 5.3.1 Soccer

Soccer is commonly played with two teams consisting of 11 players each. Soccer is played over a large field of up to 120m x 90m. Figure 5.1 shows the dimensions of a common soccer field. As most communities around the world might not have such a large field available to them, street soccer was invented. Street soccer simply uses small spaces that are available to the player such as roads, alleys and even indoor rooms as the playing ground. Goal posts in street soccer are also usually very small compared to soccer. Street soccer then evolved into futsal and gained enough popularity to be recognised by FIFA, where they organised the first Futsal World Cup in 1989.

Futsal has only 5 players on each team, and its played over a field of 42m x 25m. Figure 5.2 shows the dimensions of a common futsal field. This is much smaller than the standard soccer field, making it more accessible to most people. Futsal is played over 2 halves of 20 minutes instead of 45 minutes. As the field is much smaller and the number of people are much lower, the game tends to be more active than soccer.

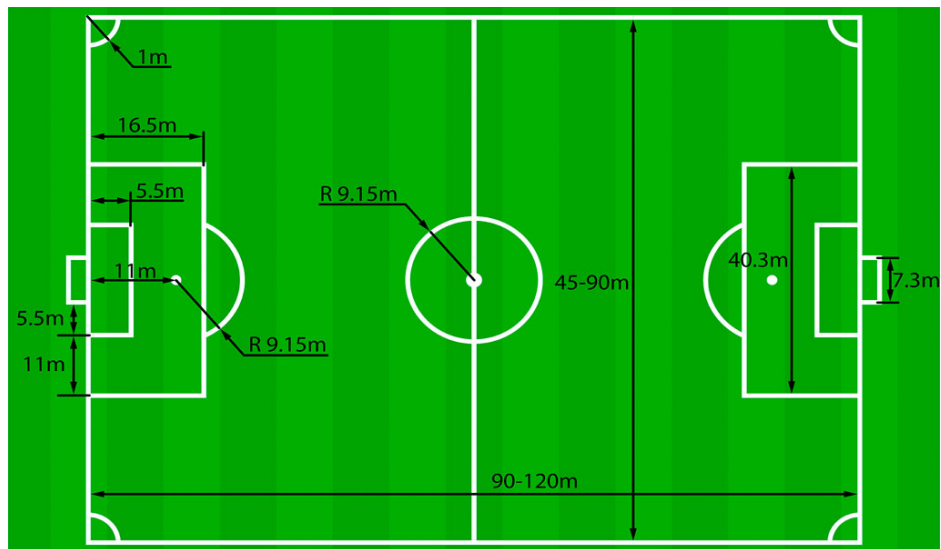


Fig. 5.1 Dimensions of Soccer field, from [6]

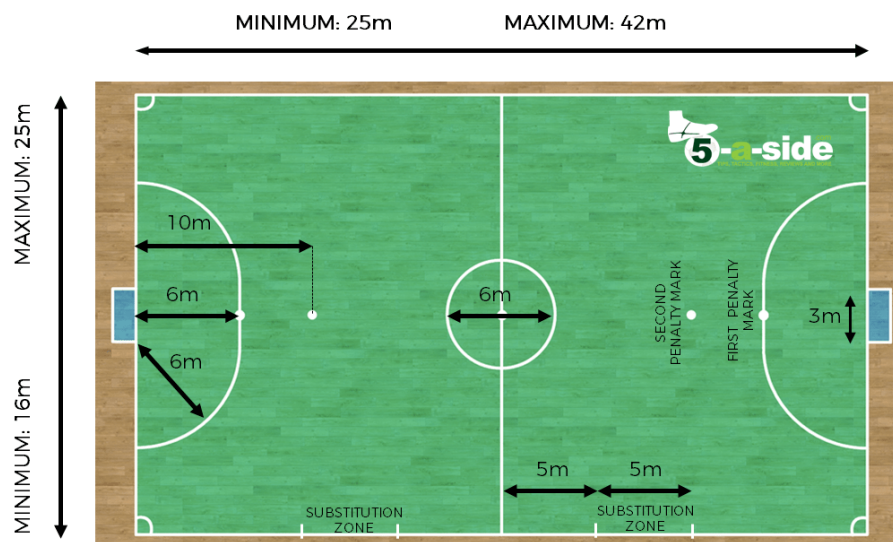


Fig. 5.2 Dimensions of Futsal field, from [7]

### 5.3.2 Basketball

Basketball is played by two teams of 5 players, where the aim of the game is to secure a higher points than the opposing team. There are two baskets on each side of the court, points are scored by based on the distance of the throw from the basket when it successfully enter the basket. Figure 5.5 shows the dimensions of a common futsal field. 5vs5 basketball became the standard for major leagues and tournaments worldwide, with NBA and FIBA World Cup being the top organisers for the games.



Fig. 5.3 Logo for 3x3 basketball



Fig. 5.4 Logo for standard basketball

3x3 is a variation of basketball, where it consists of 3 players on each team playing on a court half the size of a standard basketball court with only one basket. 3x3 basketball is relatively new and rose in popularity in the late 2000s with FIBA recognising the format and organising the first ever 3x3 tournament in 2007. The game duration is only 10 minutes, but can end shorter as the winner will be decided based on the first team that scores 21 points.

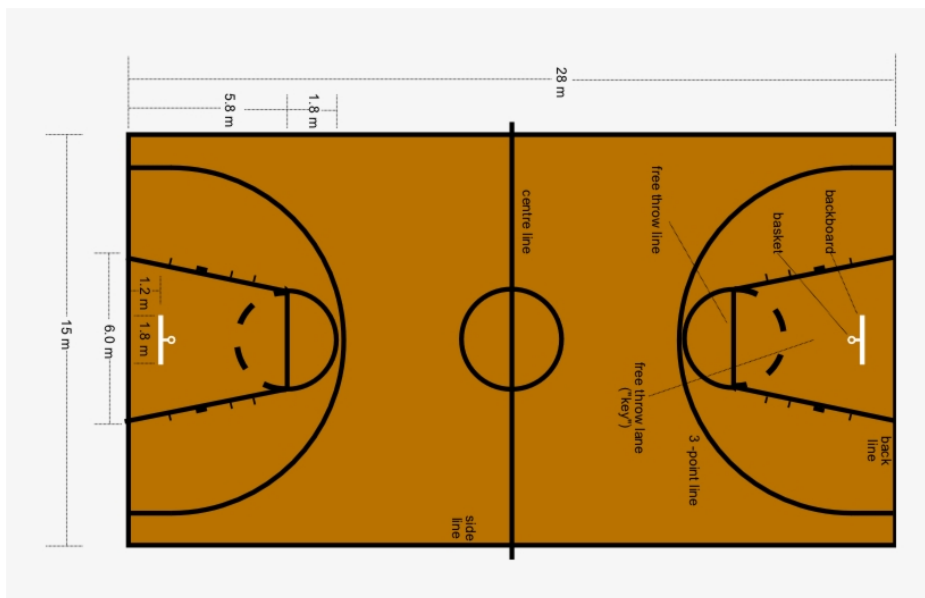


Fig. 5.5 Dimensions of Basketball court, from [8]

## 5.4 Findings and Analysis

Table 5.1 shows all the motion in mind values for all the team-based sports that was analysed.

The difference between 3x3 and standard basketball in terms of motion in mind is almost negligible. The momentum  $\vec{p}_1$  and potential energy  $E_p$  is almost the same, with standard basketball being slightly higher. By observing the lines in Figure 5.6,

Table 5.1 Motion in mind values for team-based sports games

Game	$v$	$m$	$\vec{p}_1$	$E_p$	$\vec{p}_2$	$F_2$	$GR$
FIFA Futsal 2016	0.359	0.641	0.230	0.059	-0.171	-0.279	0.064
FIFA 2018 Soccer	0.281	0.719	0.202	0.032	-0.170	-0.089	0.078
3x3 Basketball	0.476	0.524	0.249	0.113	-0.136	-0.474	0.088
Basketball	0.487	0.513	0.250	0.119	-0.131	-0.486	0.072

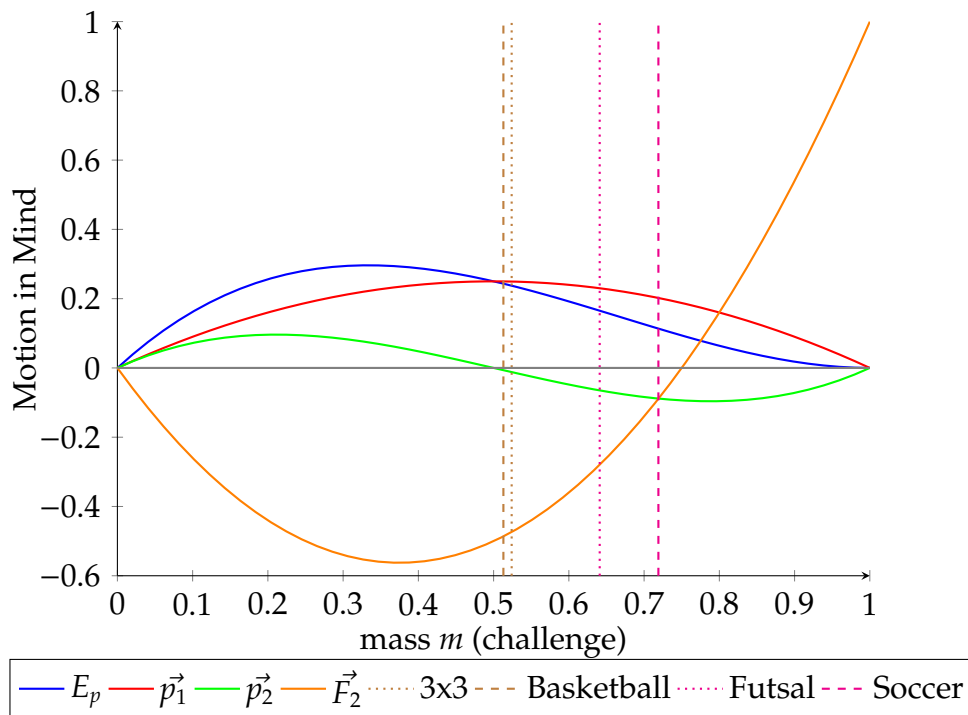


Fig. 5.6 Motion in mind values for 3x3, Basketball, Futsal and Soccer



we can see that both of the game are very close to each other, with standard basketball being closer to the  $m = 0.5$  zone.

The  $GR$  value of standard basketball is within the zone value of 0.07 and 0.08, but 3x3 is slightly outside of the range. Hence, we can say that both modes of basketball is equally competitive and entertaining. 3x3 is faster paced as the game duration is only 10 minutes instead of 40 minutes of a standard game. 3x3 also puts more of an emphasis on solo-plays instead of team-play [73] as the field size is much smaller, giving more free space to each player to utilise their own skills. This could be why the 3x3 mode gained popularity, as it provides similar experience, if not better, than the standard 5vs5 basketball.

Soccer and futsal on the other hand have a much noticeable gap. In terms of  $GR$  value, soccer is located within the sophisticated zone of 0.07 and 0.08, while futsal has a  $GR$  value of 0.064. From this, we can infer that soccer is possibly more entertaining than futsal, but futsal is more skill based than soccer. This could be due to the smaller field size and lesser number of players, as it encourages the players to perform more passes, skills and dribbles [74]. Similar to 3x3 basketball, futsal is also faster paced than soccer as the average number of goals per game is 6.77, which is significantly higher than soccer's 2.64 despite the game duration being only 40 minutes in total.

In terms of force in mind  $F_2$ , we can see that futsal is very close to the negative peak of  $m \approx 0.38$ . Games at this point implies that the game exerts force on players to ensure players acquire the abilities needed to progress the game [51]. This could be why the games have a much higher goal per game average, as players are constantly trying to move the game by scoring goals.

In terms of momentum  $\vec{p}_1$  and potential energy  $E_p$ , futsal has a noticeably higher value than soccer. Unlike other games analysed, soccer is the only game where the standard mode has lower  $\vec{p}_1$  and  $E_p$  than its alternative mode. Even basketball shows a slightly higher  $\vec{p}_1$  and  $E_p$  value, despite it being almost negligible.

The  $m$  value of soccer is quite low at only 0.281. Khalid et al. conjectured that at  $m \approx 0.21$ , the game becomes strongly engaging or addictive towards the players [51]. This might be the case for the popularity of soccer to viewers or spectators. However, by solely comparing the stats of futsal to soccer, it seems like futsal should be more popular than soccer as it contains more goals, actions and seems for engaging in general according to the motion in mind values. However this is not the case. The age of the games might be the possible reasoning behind it, as soccer existed for a very long time and has already been mainstream compared to futsal. The influence

of mass media could also be the case, as coverage for popular soccer tournaments and leagues are readily available across all platforms, unlike futsal.

## 5.5 Chapter Conclusion

In summary, we can see that team-based sports games are a good benchmark to test the motion in mind theory. By analysing soccer and futsal, our findings show that futsal should be the preferred mode as it shows better potential and engagement overall compared to soccer. However, in reality, that is not the case due to several possible reasons, such as the age of the game and overall coverage of the game by media. In the case of basketball, both 3vs3 and 5vs5 modes showed similar results, where both are equally exciting. 3x3 basketball is still relatively new compared to the standard basketball, and this could be the similar case as futsal. Both futsal and 3x3 show promising results signifying its popularity, however due to real world circumstances, both are notably inferior to the standard modes. It can be said that both 3x3 and futsal are perfectly designed in a way to maximise the entertainment value of the standard games, and possibly gain popularity in the near future.

# Chapter 6

## Conclusion

This thesis aims at analysing games with alternate modes with varying number of players in order to find the link between the number of players and the projected enjoyment or engagement towards the game using motion in mind theoris.

Firstly, we first analysed three of the notable MOBA games of the current generation: Dota 2, League of Legends and Smite. MOBA games often follow the same formula of having two teams of five players each, positioned in bases on opposite side of the virtual map which are connected via three lanes. These lanes are equipped with defensive structures which is tasked to reduce the pushing advances by players. The goal of the game is to push these lanes and reach the opponent's base and destroy it. Each player will control one character out of a pool of hundreds, where each character has their own strengths and weaknesses, making the act of choosing a character important in order to synergize with the other members in the team. Dota 2 has another mode called Solo Mid, where it is played by only one player on each team on the middle lane of the regular map for Dota 2. This mode is said to be the more skill-based version of Dota and is often used in ranking player's skills or abilities. Our findings reaffirmed this as the *GR* value for Solo Mid is very low, showing it is more skill orientated. In League of Legends, one of the popular mode with three players on each side titled Twisted Treeline was removed despite its popularity back in 2019. Our data showed that this 3vs3 mode showed more ideal values in terms of motion in mind compared to the standard mode. As this game mode was removed due to non-game reasons, we can safely assume that the game was designed well and could be a great addition in the future. While analysing smite, we found some contradicting results. The Clash and Siege mode showed not much difference to the standard mode in Smite, but both of these modes were removed due to having too few players. Players blamed that the game boring as it led to

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stalemates and that the matchmaking system for the game is a culprit for ruining the game experience. Unlike Dota 2 and League of Legends, Smite's standard mode lost its popularity to Joust, a 3vs3 mode which is played over a single lane. From the data obtained, the games were often one sided at times, but managed to stay exciting and stochastic to players. Smite's Arena mode has the highest attractiveness of play as the game is in a constant see-saw state, making it very unpredictable. Overall, we can summarise that MOBA games often prefer odd numbered players on teams and lanes, as almost every game analysed showed this pattern. This could be possibly due to the design of the in-game map and characters.

Next, we analysed one of the newer trends in online gaming, the battle royale genre. This genre focuses on player elimination, where players are eliminated across rounds until there is only one player remaining. This mechanism of reduction of players helps in changing the difficulty of the game as the game progresses, making it dynamic. We analysed three different battle royale games: PUBG, Fortnite and Fall Guys. PUBG showed that the game starts out challenging, but slowly decreases in difficulty as the player makes it into the next rounds, approaching the  $m = 0.5$  zone. Fortnite on the other hand maintains its difficulty throughout the game and only drops at the final round. By looking at the force in mind ( $F_2$ ) value for Fortnite, we can see that it maintains a positive value throughout the entire game, showing that it provides great thrill and excitement to the players. This would explain why Fortnite is more popular towards a younger audience. Fall Guys shows a slightly different scenario, where the game starts out easy and ramps up in difficulty as the game progresses. The jump in difficulty might be too much in the later rounds, as the remaining players in the final round are often high skilled as well. All three games get more interesting as they progress which can be seen in the changes in the GR value. Converse to what we conjectured previously where it was conjectured that more players would make the game more interesting.

We then analysed two popular team-based sports games: soccer and basketball. Soccer is played between two teams of 11 players each over a field, where the aim of the game is to score more goals than the opponents. Futsal is a popular variation of soccer, where it is played with only five players on each team over a much smaller field. Basketball is played by two teams of five players over a court, while 3x3, a popular variation of basketball consists of only three players on each team over half of a normal basketball court. Futsal showed more promising values in terms of motion in mind than regular soccer. Futsal had a higher average number of goals per game, and was faster paced than normal soccer. Futsal had a noticeably higher

momentum and potential energy, as well as the force in mind value being very close to the negative peak of  $m \approx 0.38$ , implying that that players are more prone to try and advance the game. Comparison between basketball and 3x3 can be said to be almost negligible as the motion in mind values obtained were almost identical. The biggest difference is that the *GR* value of 3x3 is slightly outside the *GR* zone. Hence, both formats of basketball is equally competitive and entertaining/

In conclusion, we found that number of players that are set in rules are not purely coincidental and carry its own meaning. There was a meaning in the choice of the number of players for each of the game analysed. The variation of the popular modes often showed close values in terms of *GR* and motion in mind, showing that the variation was only popular due to its good game design. External factor that are not in the game can also greatly influence the results like in Smite's Siege and Clash. Both of these modes have promising values but are ruined by external factors such as matchmaking. In the future, it would be great to re-analyse the new mode Slash, which is the combination of Siege and Slash to see if this new development would help to bring back popularity to the mode. Futsal also showed potential in being better than soccer based on our findings, but this is not the case in reality due to the influence of mass media coverage.

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