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Doctoral Dissertation

Entertainment Enhancements with Focus on the Difficulty in Stochastic and Skill Games

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Abstract

The implementation of luck and chance in games serves to create a dynamic and unpredictable experience, ensuring that outcomes are not solely determined by skill. This element of randomness can balance the playing field, giving novice players opportunities to succeed against more experienced opponents, thereby maintaining engagement and excitement. By integrating luck and chance, games can mimic the unpredictability of real-life scenarios, compelling players to adapt their strategies continuously and enhancing the gameplay's overall immersive and entertaining quality. However, several monetization strategies have been introduced, such as gacha systems and loot boxes, which blur the lines between gaming and gambling. These mechanics involve players spending real or in-game currency for a chance to obtain virtual items, often with varying degrees of rarity and value. The randomized nature of these rewards can lead to addictive behaviors, as players are enticed to make repeated purchases in hopes of obtaining desired items. This can result in significant overspending, with some players investing substantial amounts of money without a guaranteed return on their investment. The psychological impact is similar to that of traditional gambling, where the thrill of the potential reward drives continuous spending. This convergence of gaming and gambling has sparked widespread concern and debate, prompting calls for increased regulation and transparency to protect vulnerable players from exploitative practices.

In the realm of gaming, understanding the delineation between chance-based mechanics and gambling practices is crucial, prompting the investigation outlined in this dissertation. This inquiry delves into the nuances that distinguish a game of chance from gambling activities, addressing both conceptual and practical boundaries. Attention is also directed towards the intricacies of gacha games, particularly focusing on the underlying significance of their probability of winning and the pity systems. By exploring the psychology behind these mechanics, this dissertation aims to outline principles for designing an ideal gacha game that balances player engagement with ethical considerations.

The influence of team dynamics on gameplay experience forms the crux in sports and multiplayer games. Examining how team size impacts entertainment value and difficulty levels within games provides valuable insights for game designers seeking to optimize player engagement and challenge with respect to the number of players in said game. We propose a theoretical exploration of pressure within games, contrasting it with the concept of mass in the motion in mind model to explain the difficulty of games with respect to the number of players. By elucidating the essential disparities between these measures, this inquiry contributes to a deeper understanding of psychological dynamics in gaming environments.

Finally, this dissertation ventures into the realm of player emotion, investigating potential links to the motion in mind model. By probing the intersection of cognitive processes and emotional states within gaming contexts, this research seeks to uncover underlying mechanisms driving player experiences. We will be conducting several experiments in the domain of gacha and multiplayer games to definitively establish the connection between players' emotional states and previously hypothesized cognitive measures.

Collectively, the research questions raised from this dissertation form a comprehensive exploration of various facets within the gaming landscape, offering insights into conceptual boundaries, game design principles, team dynamics, psychological constructs, and their interconnections.

Keyword: *Game refinement theory*; *Motion in mind*;*Jerk*; *Reward frequency*; *Gacha games*; *Multiplayer games*; *Pressure*; *Addiction*

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Chapter 1

Introduction

1.1 Chapter Introduction

In the realm of entertainment, the integration of skill and chance plays a pivotal role in shaping user experiences. From traditional board games to modern digital simulations, the interplay between skill-based challenges and stochastic elements adds depth and intrigue to various forms of entertainment. Skill-based games require players to rely on their abilities, strategies, and tactics to succeed, often leading to a direct correlation between a player's proficiency and their success. In contrast, stochastic games introduce elements of randomness and chance, making the outcomes less predictable and adding an element of unpredictability regardless of a player's skill level. This chapter serves as an introduction to exploring the complexities and enhancements within this domain, delving into the fusion of skill and stochasticity and its impact on gaming experiences. By examining how skill-based and stochastic elements influence difficulty, we gain insight into how they can create varied and engaging user experiences.

1.2 Background

Monetization models in games have evolved significantly over the years, adapting to changes in technology, player preferences, and market dynamics. Two primary models dominate the monetization strategies in the gaming industry: the Pay-to-Play (P2P) model and the Free-to-Play (F2P) model. In the Pay-to-Play model, players are required to purchase the game upfront before gaining access to it. On the other hand, the Free-to-Play model allows players to download and play the game at no initial cost, relying instead on micro-transactions and other in-game purchases to generate revenue. This model has become increasingly popular, especially in mobile gaming and online multiplayer games. However, hybrid models have popped up recently, where they combine elements of both P2P and F2P models to maximize revenue and player engagement.

A study by Harvard Business School found that loot boxes generate about $15 billion annually, with 90% of this revenue coming from a small group of heavy spenders, often referred to as "whales" [6]. This intense spending is driven by the randomized rewards, which mimic gambling behaviors and can lead to excessive and compulsive purchasing [7]. Some previous work outlined that gambling and loot boxes are not per-se gambling, but their lack of transparency leads to players feeling addicted [8], stressing that self-regulation is more critical than government-imposed regulations.

The rise of micro-transactions has led to increased scrutiny and regulatory actions worldwide. Concerns about the potential for gambling-like behaviors, particularly with loot boxes and gacha systems, have prompted some countries to implement stricter regulations [9]. China's new regulations aim to curb this behavior by limiting the amount of money minors can spend on gacha games and enforcing strict disclosure of the odds for obtaining certain items [10]. These measures are part of broader international efforts to mitigate the risks associated with these monetization strategies. For example, Belgium has banned loot boxes altogether, while other countries like the Netherlands have imposed partial bans [7, 9]. In the United States, the Federal Trade Commission has been investigating the impact of loot boxes, particularly on children, since 2018. This has led to workshops and calls for public comment on the issue. Additionally, some gaming companies have started to adopt self-regulation measures, such as disclosing the probabilities of winning certain items and enabling self-exclusion from purchasing loot boxes for players who request it [11].

The dissertation aims to delve into the phenomenon of addiction in random reward games, particularly Gacha games, by investigating the underlying factors contributing to players' addictive behaviors. As gacha games are purely random, they are considered fully stochastic and cannot be influenced by player skills. The difficulty in a stochastic game can be defined by the probability of an occurrence, such that a lower likelihood signifies a difficult game. The study seeks to establish clear distinctions between gaming and gambling, identifying the border that separates these activities. Furthermore, the research strives to pinpoint key factors for designing an ideal Gacha game that balances engagement and avoids addictive tendencies.

Pressure while gaming is a significant phenomenon that has been examined in various scientific studies. Research has shown that the competitive nature of many video games can induce high levels of stress and anxiety in players. Hardcore players were found to enjoy comparing achievements with other players, leading to motivation to play until they lose track of time [12]. Another study found that inter-group competitions leads to higher enjoyment compared to pure competition or cooperation in games [13]. The social aspects of gaming also contribute to this pressure, as players often feel the need to meet the expectations of peers and avoid negative judgments. Previous work highlighted how social pressure could lead to excessive gaming [14].

Choking in games, a phenomenon where players fail to perform under pressure despite their skills and practice, is a well-documented issue in both competitive and casual gaming environments. This psychological occurrence often manifests during high-stakes moments, such as final rounds in tournaments or critical in-game decisions. These findings are consistent across various types of games, from physical sports to eSports, indicating that the underlying psychological mechanisms of choking are similar. Effective coping strategies, such as mindfulness and pressure acclimatization, have been shown to help mitigate these effects, allowing players to maintain their performance under stress [15].

In addition to exploring the psychological aspects of gaming, this dissertation also aims to introduce a novel metric for measuring pressure in games, with a focus on the relationship between pressure and the number of players involved. The research endeavors to determine the optimal level of pressure required to motivate players while examining the subjective nature of game difficulty concerning perceived pressure. Furthermore, the investigation extends to team-based games, studying the distribution of pressure among players within a team setting.

To enhance the understanding of player experiences, this dissertation explores the feasibility of measuring player emotions through electrocardiograms (ECG), namely heart rate monitors. This includes assessing if ECG readings can serve as a reliable indicator of player emotions during gameplay. Additionally, the study delves into the impact of the motion in mind metric on players, utilizing ECG data to measure how cognitive and emotional states are influenced by in-game motion.

Overall, the research encompasses a comprehensive exploration of the psychological, design, and physiological aspects of gaming, focusing on addiction, pressure, teamwork dynamics, and emotional responses measured through ECG to enhance the entertainment aspects of a game.

1.3 Problem Statements

This dissertation has five main research questions which are listed below:

- **RQ1 : What is the boundary between a game of chance and gambling?** Gacha games are stochastic in nature, being completely reliant on chance like gambling, and are frequently compared in various media. The similarities often make it difficult to differentiate between games and gambling, and we hope to propose a metric that helps to distinguish them.

- **RQ2 : What is the significance behind the pity system in gacha games and how can we design an ideal gacha game?** The pity system is a mechanism introduced to help create a ceiling price for gacha games and ensure players don't overspend. The implementation of pity system might decrease the randomness and stochastic aspect of the game. Hence, the pity system of various games should be studied to design an ideal pity counter to maximize the entertainment for players while ensuring profit for developers.

- **RQ3 : How does the number of player in a team affect the game's entertainment and difficulty?** A team game is often partially cooperative and competitive, where players are grouped into teams and try to triumph over other teams. Competitive games are often heavily skill-based, with minor stochastic elements. The number of players in a cooperative game would influence the game differently compared to a competitive game. Several games were analyzed and compared to find possible ways to improve games further.

- **RQ4 : What is the essential difference between pressure in games and mass in the motion in mind model?** Previous studies in the realm of motion in mind described the game's difficulty based on its scoring rate. However, we feel skill-based games often have subjective difficulty stemming from the player composition. A new metric for pressure is proposed to explain the subjective difficulty players feel in different competitive game settings.

- **RQ5 : Can player's emotion be linked to the motion in mind model?** Motion in mind is used to study various games and analyze their entertainment value to players. Previous work in the realm has mostly been theoretical. This dissertation aims to find a link between motion in mind and human emotions in both stochastic and skill-based games.

1.4 Research Objectives and Significance

Games that capitalize on random reward mechanisms, exemplified by Gacha and loot boxes, have faced criticism for being perceived as predatory, particularly in their potential to encourage gambling tendencies among younger players. Gacha games are completely stochastic, and the player's skill has zero influence on the outcome of each attempt, similar to lotteries. Previous research has established a connection between exposure to these games and the development of gambling addiction [16,17]. To address this concern, a detailed examination of the Gacha mechanism is essential, as it could provide insights into mitigating the risks associated with Gacha game addiction. Establishing a clear boundary between gaming and gambling becomes imperative, ensuring that games do not excessively lean towards gambling elements. Striking this balance is crucial in minimizing the risk of addiction while preserving the entertainment value of games, thereby paving the way for potential applications in addressing broader addiction issues.

This dissertation also discusses the pity system implemented in gacha games, which guarantees players a rare item if they have failed to obtain it after several attempts. The probability of obtaining this rare item is often infinitesimally small, leading to the necessity for the existence of the pity system. The difficulty in a stochastic game can be equated to the probability of a favorable occurrence. Hence, a gacha game with a lower probability of obtaining a rare item is deemed more difficult. The ideal pity counter should be determined to maximize player satisfaction and improve gacha games as an entertainment.

Team games typically blend cooperation and competition, where players are organized into teams striving to outperform others. Competitive games emphasize skill, often with minimal stochastic elements. The number of players in a cooperative versus competitive setting significantly impacts gameplay dynamics regarding difficulty, scores, and game length. Various games have been scrutinized and compared to identify avenues for enhancement of each game. Prior research on motion in mind only considered game difficulty based on its scoring rates. However, this dissertation contends that the subjective challenge in skill-based games hinges more on player and team dynamics. Delving into the intricacies of difficulty and pressure in games presents an opportunity to craft an optimal gaming experience for players.

Moreover, the study seeks to validate the impact of the motion in mind metric on a player's emotional state using electrocardiograms (ECG). This empirical approach aims to provide concrete evidence regarding the influence of in-game motion on a player's experience, substantiating theories that have been previously proposed. By employing ECG data, we can gain a deeper understanding of how the motion in mind metric contributes to the emotional landscape of gameplay, offering valuable insights for game developers and researchers alike.

1.5 Structure of Dissertation

There are five further chapters in this dissertation. The remaining chapters are organized as below:

- **Chapter 2: Literature Review** This chapter covers previous research that is done on the domain of games. The first section covers the motion in mind model which is the main theory used for evaluating the entertainment value of games in this dissertation. The second section then delves deeper into the popularity of challenging video games. The following section will give an overview of the gacha mechanism that is widely used in video games today. Finally, previous works done on the domain of addiction theories are studied to better understand the emotional impact of gambling.

- **Chapter 3: Evaluating Random Reward Games** This chapter revolves around the gacha mechanism in video games and the entertainment evaluation of it using motion in mind model. The first section gives a brief background of the gacha game used for data collection in this dissertation: Genshin Impact, a popular role playing game (RPG) game that utilizes gacha mechanisms to obtain new characters and weapons. Following section explains the data collection and analysis done for the game. The third section describes in detail what makes a game of chance to be categorized as gambling. The fourth section shows our suggestions on improving the gacha system while making comparisons with other gacha games in the market. Finally, the significance behind repetitive plays will be detailed to better understand why it is important for a gacha game.

- **Chapter 4: Pressure and Difficulty in Games** This chapter focuses on the evaluation of pressure in games and its difference to mass in the motion in mind model. The first section shows the reasoning behind the formulation of pressure in mind based on previous findings in the realm of motion in mind. The second section shows the finding and analysis of various games and sports studied in this dissertation which range from variations of soccer, basketball, badminton and multiplayer online battle arena (MOBA) video games. The final section highlights the key differences of pressure and mass in the motion in mind models.

- **Chapter 5: Player Emotions and its Relationship with Motion in Mind** This chapter details the various experiments done in this dissertation which involved human players. Firstly, the procedures of the experiments are described in detail as well as precautions taken to ensure accuracy of results. Next, the results obtained are analysed using various theories to understand the reasons behind the outcomes.

- **Chapter 6: Conclusion** This chapter covers and summarizes the outcomes of each chapter in the dissertation. The first section addresses the research questions that was initiated in the first chapter. Concluding remarks are then made, followed by future work suggestions to improve the findings in this dissertation.

Chapter 2

Literature Review

2.1 Chapter Introduction

This chapter presents a review of current works done in the domain of motion in mind model, which is used as the basis for this dissertation. The motion in mind theory uses natural physics as a basis to explain the uncertainty and entertainment aspects of a game. This chapter also gives a brief overview of the gacha mechanism in video games and its impact to games. The controversies behind the implementation of gacha mechanics and the introduction of the pity system will be detailed to further understand the reasons behind the lucrativeness of these games. Finally, popular addiction theories will be studied to understand the reasons behind the attractiveness of gambling. Possible connections between gambling and gacha will also be examined. A brief summary will be made in the end to justify the research done in this dissertation.

2.2 Motion in Mind Model

Game Refinement Theory is a theory that was proposed by Iida et al. [18], and it focuses on the sophistication and the uncertainty of the outcome of a game, which in turn increases the attractiveness of a game [19]. 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.

Game refinement theory proposes the GR measure, a metric derived from the game progress model, to identify the deterministic and stochastic aspects of the game. Based on previous works on the application of game refinement theory on various games, it was found that an ideal game has a GR value within the range of $GR \in [0.07, 0.08]$, which is dubbed the "comfortable" zone. The "comfortable" zone was identified based on shared patterns of games that were found to be enjoyable and attractive to players of both beginner and advanced skill levels [20].

The formula for measuring GR differs depending on the type of the game being analyzed. In the domain of board games, the branching factor and depth of the game are used to denote the average number of possible moves and game length, expressed as B and D, respectively. In score-based games like soccer, the total goals (G) and the total attempts at goals (T) are used to evaluate GR. Equation (2.1) shows the formula for evaluating GR.

$$GR \approx \frac{\sqrt{B}}{D} \approx \frac{\sqrt{2G}}{T} \approx \sqrt{a} \tag{2.1}$$

There may be instances where two teams have the same GR value but feel entirely different while attempting to score. This can be explained by the change in mind's acceleration throughout the game, which can be denoted using jerk j. Jerk represents the change in informational acceleration (the magnitude of thrills, the tendency of getting attractiveness, and related to game addiction), which is linked to an addictive-like event due to the tendency of motivation retention thus, denoted as AD value [21]. The "comfortable" zone for AD is within the range of $AD \in [0.045, 0.06]$.

Similarly, AD value is evaluated differently depending on the type of the game. Equation (2.2) shows the formula for evaluating AD.

$$AD = \frac{\sqrt[3]{3B}}{D} = \frac{\sqrt[3]{6G}}{T} = \sqrt[3]{j} \tag{2.2}$$

According to the game progress model, we can express the rate of solving uncertainty as velocity v while the magnitude of challenge or resistance faced by the player during the game as mass m. In the current context, v generally means the rate of solving uncertainty, whereas m implies the difficulty of solving such uncertainty ($m = 1 - v$) [22]. Velocity can also be expressed as the winning or scoring rate for a scoring-based game. Equation (2.3) shows the formula for evaluating velocity v for both board and scoring-based games.

$$v = \frac{B}{2D} = \frac{G}{T} = 1 - m \tag{2.3}$$

Reinforcement theory is a psychological principle proposed by [23], suggesting that action is shaped by its consequence, and the behaviors can be shaped through reinforcement, punishment, and extinction [24]. There are four notable reinforcement schedules: continuous, partial, fixed-ratio, and variable-ratio reinforcement. For this research, we will only focus on the variable-ratio reinforcement schedule. The variable-ratio schedule perfectly explains lottery, gambling, and gacha games, where reinforcement (reward) is given after an unpredictable or random number of responses. The variable-ratio reinforcement schedule helps maintain player interest as the regular small wins help to disguise the losses suffered previously [25], leading to addiction.

In variable-ratio schedules, the parameter N shows the average reward frequency, where $1 < N \in \mathbb{R}$. In the context of games, winning the game corresponds to obtaining a reward [26]. As such, N can be expressed as the inverse of the winning rate v.

Although there is a limit to how much G-force humans can physically feel, our minds might experience a different type of gravity when playing games. This "gravity in mind" or "gravity of play" is a subjective feeling of G-force caused by the acceleration of the game's progress. We conjecture that this feeling can be approximated by the ratio of gravity of play over the gravity in mind, which can be approximated by the square root of the reward frequency (represented as $\sqrt{N}$).

Motions in our mind can be expressed using velocity, acceleration, and jerk, where each metric shows the amount of solved uncertainty throughout the game's progress.

We show, in Figure 2-1, the trend and intersections of two lines and two curves depicting the distance y_0, velocity y_1, acceleration y_2 and jerk y_3 in our mind throughout the progress of a game.

$$y_2 = \frac{1}{2}a_0\ t^2 \quad \text{with} \quad a_0 = GR^2 = \text{gravity of mind} \tag{2.4}$$

$$y_3 = \frac{1}{6}j\ t^3 \quad \text{with} \quad j = AD^3 \tag{2.5}$$

Gao *et al.* [21] observed that competitive games are most entertaining and addictive when the levels of GR and AD are equal, which can be expressed as the intersection between lines y_2 and y_3 from Figure 2-1. The cross point between y_2 and y_3 is given by $t_{23} = 3\frac{a_0}{j}$. A new gravity of play is produced by the jerk in mind (y_3 curve), and the certainty can expressed as Equation (2.6).

$$y_{23}(t_{23}) = \frac{9}{2}\phi^6 \quad \text{where} \quad \phi = \frac{GR}{AD} \tag{2.6}$$

The intersection between y_1 and y_2 will give us $t_{12} = \frac{2v}{a_0}$. Based on Figure 2-1, $t_{12} = t_{23}$. Then, we can obtain Equation (2.7).

$$\begin{aligned} \frac{2v}{a_0} &= \frac{3a_0}{j} \\ a_0^2 &= \frac{2jv}{3} \end{aligned} \tag{2.7}$$

A new thing, characterized by its velocity, is created by a mixture of the gravity in mind (y_2 curve) and jerk in mind (y_3 curve) which produces the gravity of play a, denoted in y_2'.

$$y_2' = \frac{1}{2}at^2 \quad \text{where} \quad a = \text{gravity of play} \tag{2.8}$$

The cross-point between y_2' and y_3 gives us $t_{23}' = \frac{3a}{j}$. The cross point between y_0 and y_3 gives us $t_{03} = \sqrt{\frac{6}{j}}$. As $t_{23}' = t_{03}$, we can rearrange it to obtain Equation (2.9).

$$
\begin{aligned}
\frac{3a}{j} &= \sqrt{\frac{6}{j}} \\
\frac{9a^2}{j^2} &= \frac{6}{j} \\
a^2 &= \frac{2j}{3}
\end{aligned}
\tag{2.9}
$$

Let g be the magnitude of gravity, that is, the ratio of gravity of play a over gravity in mind a_0. Using (2.7) and (2.9), we can obtain (2.10).

$$
g = \frac{a}{a_0} = \frac{\sqrt{\frac{2j}{3}}}{\sqrt{\frac{2jv}{3}}} = \sqrt{\frac{1}{v}} = \sqrt{N} \tag{2.10}
$$

Thus, we have (2.11).

$$
\frac{a}{a_0} = \sqrt{N} \tag{2.11}
$$

Conjecture 1 (magnitude of gravity) *The level of gravity of play, denoted as g, is connected to the frequency of obtaining rewards. Specifically, g is equal to the square root of the reward frequency, denoted as $\sqrt{N}$. Human beings can handle higher levels of gravity of play without experiencing any uncomfortable or nauseous sensations, and there is currently no known upper limit to this tolerance.*

Players often play a game several times to gain confidence and certainty in their skills and the outcome of the game. This ensures that the game is replayable and that the player will want to play it again. We conjecture that the number of attempts needed for a player to become confident in the game's outcome can be estimated by dividing the total game length y_{02} with the optimal game length y_{23}, as shown in Equation 2.12.

$$
\frac{y_{02}}{y_{23}} = \frac{4}{9a\ \phi^6} \tag{2.12}
$$

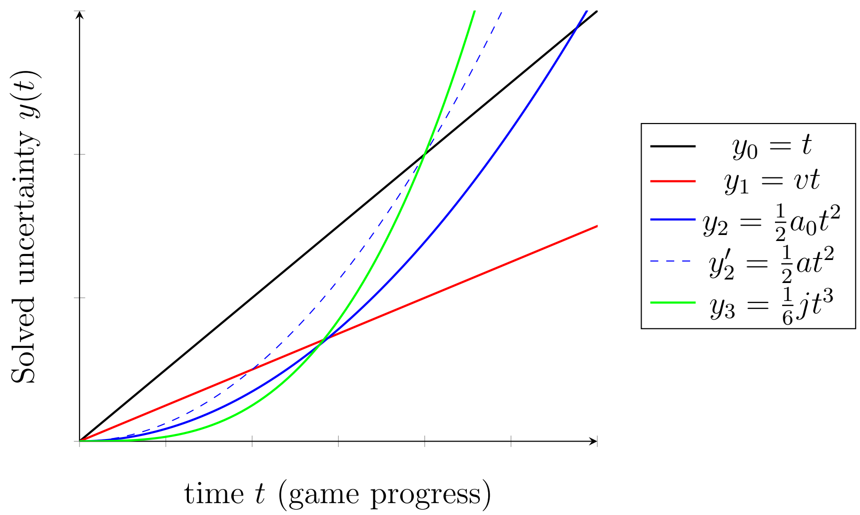

Figure 2-1: The depiction of the intersections between v, a, and j in the context of solved uncertainty over game progress

By assuming $GR = \frac{1}{12}$, we can further simplify Equation 2.13 to be expressed only in terms of ϕ as shown in Equation 2.13.

$$\frac{y_{02}}{y_{23}} \simeq \frac{64}{\phi^6} = \left(\frac{2}{\phi}\right)^6 \approx N^2 \tag{2.13}$$

Conjecture 2 *The number of play attempts required for obtaining confidence in the outcome of the game can be estimated using* $\left(\frac{2}{\phi}\right)^6$*, where it is approximately the square of the reward frequency,* N^2.

The value of ϕ shows how many times a game should be repeated for the players to obtain confidence in the outcome of the game. Stochastic games such as lottery and gambling have a lower ϕ, which would make the player repeat the game hundreds or thousands of times, while educational games should ensure that $1 \leq \phi \leq 2$ to not bore the players. Educational games often exclude stochastic elements, making repetitions boring due to their predictable outcome. Hence, balancing GR and AD is crucial in designing an ideal game.

2.3 Background on Gacha in Video Games

Introducing randomness into monetization proved to be profitable and is becoming increasingly popular in the gaming industry, with over 50% of mobile games and 36% of desktop games containing some form of loot boxes [27]. Instead of implementing static pricing to items, it has proven profitable for the seller to use a stochastic pricing process, which resembles trading card collection, penny auction, and blind boxes [28]. Over time, the gacha system has been included in a variety of mobile and video games, including RPG, strategy, and simulation games, and has become a popular monetization model for game developers.

It is worth noting that the first gacha games in digital format are not well documented, but it is often cited that the first mobile gacha games appeared around 2010 with the release of Dragon Collection [29]. These games were simple and not as advanced as the current ones but offered randomized virtual items to players. The gacha mechanism was also applied to free-to-play games where players can earn in-game currency or points to use the gacha system. This allows players to enjoy the game without spending money; however, it might tempt players to spend real money to obtain items much quicker than they can naturally by playing the game.

2.3.1 Controversy with Gacha

Back in 2017, the majority of the players hated the inclusion of loot boxes in games as it makes the game "pay-to-win" with a noxious random generator [30]. Players preferred paying for the items traditionally as they knew what they were getting for the money spent. As loot boxes randomize the rewards, the chances of obtaining the item you want are significantly low, and there is a chance to obtain duplicate items, which often results in a waste of resources. The inclusion of loot boxes ruined the hype for the highly anticipated Star Wars Battlefront II game in 2017, where the developers removed the loot boxes 24 hours before the game's release after massive backlash from players [31].

Japan's controversy with gacha or loot boxes came long before the rest of the world. The expenditure of gacha became a social problem in Japan, where it became controversial back in 2012 as news outlets reported that the Consumer Affairs Agency would ban "kompu gacha" (complete gacha) based on the regulations of the Act Against Unjustifiable Premiums and Misleading Presentations [32]. Kompu gacha requires players to obtain a complete set of items through gacha mechanics to then obtain a rare item (the grand prize) [33]. Similar gacha systems like bingo gacha were also banned, where the rewards are placed on a bingo sheet, and the grand prize can only be collected by completing columns or lines of the bingo [34].

2.3.2 Pity system in Gacha

Granblue Fantasy introduced a safety net to guarantee the reward in the case that the player is extremely unlucky in 2016, called the pity system [28]. This pity system helped create a ceiling price for the gacha in question, and it has been quickly adopted by most gacha games thereafter, with their specific parameters for various games. In Granblue Fantasy, players will obtain a "spark" each time they play the gacha, and players can exchange 300 "sparks" in the shop to receive the featured highest-rarity character [35]. Several gacha games include pity systems without using "spark" exchanges, such as Genshin Impact, which guarantees the player to receive any 5-star character after 90 attempts or 180 attempts for a featured character.

The pity system became a double-edged sword that motivated the player to play the gacha. As the pity in Genshin Impact persists throughout the game, players engage in an action called building pity or farming pity. Since players are guaranteed to receive a 5-star character after 90 attempts in Genshin Impact, they play the gacha every time they earn enough gems from playing the game. There are many opinions on building pity, with most being negative [36,37]. For example, a player who wanted a specific character that will be released in the future would build pity by pulling in the current gacha for a different character. By building the pity close to 90, they can obtain the character quickly when it is released in the future. However, this often backfires as players might obtain a different character while building the pity.

Building pity shows some addictive behaviors towards gacha, where players are thrill-seeking and making decisions impulsively [38]. Players expressed regret for having pulled in the gacha when they initially had no plans to or insisted that they would stop at a certain number of pulls. Players also showed high frustration due to their bad luck, which led to spending more than intended. This pattern of behavior is similar to those displayed for gambling addiction.

2.4 Gambling and Addiction Theories

The Illinois Institute for Addiction Recovery has identified four phases in gambling addiction, namely the winning phase, the losing phase, the desperation phase, and the hopeless phase [39, 40]. Free-to-play (F2P) games are notorious for giving tons of rewards during the early stages of the game, enticing new players to try out and commit to the game, then gradually reducing the rewards towards the end game to slow the progression of the game. In the early stages of gacha games, players often start with a big win from the gacha due to the increased rewards, leading to excitement and a positive view of the gacha mechanics.

During the desperation phase, there is a higher risk of the gamblers committing offenses in order to sustain their habitual behaviors of gambling [41]. However, the last two gambling phases might not apply to gacha games as most players often quit the game before reaching this phase. It is worth noting that the inclusion of the pity system in the gacha makes it impossible to continuously be in the losing phase, as the player will eventually win due to the pity. Therefore, gacha players frequently find themselves between winning and losing phases.

According to addiction theory, addiction can be defined as "a persistent behavioral pattern characterized by a desire or need to continue the activity which places it outside voluntary control; a tendency to increase the frequency or amount of the activity over time; psychological dependence on the pleasurable effects of the activity; and, a detrimental effect on the individual and society" [42].

However, Walker also noted that gambling could not be generalized using addiction theory as the purpose of gambling is different from psychological addiction like drug addiction [42]. Addiction theory states that the motivation should be primarily for pleasure or excitement. In general, gamblers perceive enjoyment and excitement from winning a large sum of money, where the primary motivation is to win, and pleasure is only a by-product of winning. The same could be applied to the gacha itself, as players only feel enjoyment when they obtain the character they want from the gacha. However, the fundamental distinction between gambling and gacha lies in the nature of the rewards; gambling victories yield items of monetary value, whereas gacha rewards hold no value beyond the confines of the game.

In the context of drug addiction, two leading causes of addiction can be explained using genetic theory and exposure theory [43]. Genetic theory, also known as addictive inheritance, describes how some forms of addiction are hereditary. For example, studies showed that children born from alcoholic parents who are adopted into non-alcoholic families have significantly higher rates of alcoholism. However, this might not apply to gacha itself, as playing gacha would not affect an individual on a genetic level.

Exposure theory, on the other hand, is more applicable to gambling and gacha addiction. Greater availability of gambling is highly associated with pathological gambling [40]. Most live service games now sell simulated gambling via gacha or loot boxes as a monetization strategy. Exposure to gambling-themed games and gacha games may normalize the act of gambling despite not spending money on the games, as it increases the player's confidence in winning in gambling and affects their perception of gambling [44].

Fear of missing out (FoMO) was first introduced in media outlets in the early 2010s, where it is a condition that causes an individual to feel social anxiety that others are having fun or rewarding experiences without them [45]. FoMO is often associated with lack of sleep, emotional tension, concentration, and dependence on social media for gratification [46]. Today's marketing strategies try to capitalize on FoMO by limiting items and forcing players to buy them before they disappear forever.

Gacha games often have multiple gacha interfaces called gacha banners, with the common scenario of containing a permanent and a limited banner. Limited banners are frequently time-limited, where the items offered are only available for a short duration [34]. The forced inclusion of time pressure causes the FoMO effect on players, where they feel pressured to obtain the items from the gacha. Item bundles in the Diablo Immortal game do not tell players if the bundles will stay in the shop permanently or will disappear eventually, creating a FoMO effect on players to not miss out on the offer [47].

Collectionism was pointed out by players as a motivation for acquiring gacha items, with players placing a higher value on items they need to complete their collection rather than necessarily on high-rated game items [48]. Some players see the items obtainable from the gacha as a collection that needs to be completed, which can be extremely expensive.

For example, to maximize the potential of a 5-star character or weapon in Genshin Impact, players must obtain duplicate copies of the item and use the material to upgrade the aforementioned character or weapon. Assuming the worst-case scenario, it would cost up to US$2,145 to maximize a 5-star character while maximizing 5-star weapons would cost US$4,200 [49, 50]. As of March 2023, there are 31 characters and 36 weapons of the 5-star rarity [51], which would sum up to a total of $217,695. You could perhaps buy a property with that amount of money, but instead, some players decide to spend that money on a ”free” game simply to complete their collection.

The psychology of being a ”completionist” could be explained by looking at three key factors: reward motivation, hoard mentality, and irrational fears [52]. Reward motivation is the satisfaction received when players receive medals, trophies, or achievements for completing a task. Achieving all these medals or trophies drives players to complete the game, which provides no tangible benefits in real life, only for bragging rights and self-perceived superiority over others.

Hoard mentality is a psychological condition of wanting to collect and keep everything despite the action not providing any benefits whatsoever. Hoarding disorder makes it difficult for an individual to discard or get rid of a possession, resulting in them gradually gathering many items, regardless of their actual value [53, 54].

The irrational fears stem from FoMO, where the individual feels incomplete or less competent when they did not complete the game [52]. Players see a certain beauty or symmetry in the completion screen and can only put down a game once they sufficiently complete it.

Prospect theory is the best way to describe how people evaluate risk in experimental settings. Prospect theory states that gains and losses are valued differently, with more weight on perceived gains than losses. Gains and losses are subjective to expectations or aspiration levels that cause difficulty to be generalized in economic context [55, 56]. Prospect theory could be applied to explain the attractiveness of gacha.

As the probability of gains is generally perceived as more significant than its actual value, it makes naive buyers believe that they will try their luck one last time and quit after that but ultimately continue to purchase until they finally receive the goods [28]. In gacha games, "gains" could be generalized as getting the limited item from the gacha within a reasonable cost.

Discounting theory explains how current costs and benefits are worth more than those occurring in the future as there is an opportunity cost to spending money now, and there is a desire to enjoy benefits now rather than in the future [57]. Human behavior often implicitly accounts for discounting, especially when it is related to health. For instance, smoking and drinking might give pleasure currently while incurring future costs in terms of health effects. Despite the detrimental health effects, many are still willing to pay the opportunity cost of enjoying themselves currently.

Despite the increased cost of newly released games, movies, or devices, many people are willing to pay the extra cost for the new product rather than waiting until the price falls. Similar could be applied to gacha games, where items might not reduce in price but increase in availability. Characters in Genshin Impact are time-limited to increase the perceived rarity but are usually available again in the future after a couple of months called a re-run. Despite that, more players are willing to obtain the characters on their original release than wait for the re-run as they want to take advantage of the opportunity to enjoy the new character early.

2.5 Chapter Summary

In this chapter, several works related to this dissertation were studied. The motion in mind model was examined in detail to uncover the reasoning behind each formulation and its application to determine the entertainment value behind games. Backgrounds of gacha mechanisms and their controversies were also addressed as this dissertation focuses on stochastic games. Addiction theories were also studied as previous works addressed the similarities between gacha and gambling. These studies are essential as they serve as the basis for research done in this dissertation.

Chapter 3

Research Methodology

3.1 Chapter Introduction

This chapter outlines the research methodology of this study, which aims to analyze various types of games, ranging from stochastic and skill based games. The methodology includes data collection methods, experimental design and the methodologies used to analyze the findings.

3.2 Data Collection

The subsection below details the data collection measures for each game that has been analyzed in this dissertation.

3.2.1 Gacha from Genshin Impact

The gacha from Genshin Impact was used to study stochastic games as gacha games are a form of random reward games. Data collection for the game was done by collecting actual play data of the gacha from Genshin Impact recorded using Genshin Wish Export [1], an open-source external application created by a fan to record and visualize the gacha history. The data includes the number of attempts made and

[1]available on `https://github.com/biuuu/genshin-wish-export`

the number of items of each rarity obtained from the attempts. By using the real play data, it helps to provide insights into the actual in-game experiences of players, allowing for an analysis of the probabilities and outcomes within the gacha.

3.2.2 Sports Games

For the sports games included in this study such as soccer, futsal, basketball, 3x3 and badminton, data were collected from officially available online resources. This included game scores, player statistics, and match outcomes. The chosen sources were reputable platforms such as the Badminton World Federation (BWF) page for Olympics [2], Entertainment and Sports Programming Network (ESPN) official page [3], and FBRef [4] that provide accurate and comprehensive coverage of sports events, ensuring that the data used in this study was reliable and up-to-date.

3.2.3 MOBA Games

For Multiplayer Online Battle Arena (MOBA) games, the data used in this paper was collected in a previous work [58] based on real games played by players online. The data stresses on the skill levels of players by collecting data from official tournaments whenever available. When analyzing game modes which had no tournament data, data was then collected from online matches played by high ranking players over the ranked matchmaking system.

3.2.4 Overcooked! 2

The gameplay data from the cooperative game Overcooked! 2 was also collected to differentiate between competitive and cooperative games. A total of six players participated in this experiment, playing the game in various team configurations ranging from one to four players. The players played a total 12 games where the number of successful orders and the scores obtained were recorded for each session.

[2] available on `https://olympics.bwfbadminton.com/news/?ncat=paris-2024`
[3] available on `https://www.espn.com/nba/stats`
[4] available on `https://fbref.com/en/comps/1/World-Cup-Stats`

This experiment allowed for an analysis of how team size affects performance in cooperative game.

3.3 Experimental Design

To assess the physiological impact of gacha and cooperative games, a heart rate monitor was attached to participants during the Genshin Impact gacha simulation and the Overcooked! 2 experiments. The heart rate data was recorded throughout the experiment to observe changes in heart rate in response to in-game events. This data was analyzed to provide insights into the physiological effects of different types of gaming experiences. A questionnaire was also given to respondents after the experiment to give a better understanding on the emotions felt during the game.

3.4 Data Analysis

The data collected from all sources were then analyzed to obtain the motion in mind metric of each game. For gacha games, the reward frequency was highlighted as it depicts the overall game progress and is crucial in determining the entertainment value to players. For sports and MOBA games, the number of players was given a greater focus by comparing the velocity, mass and pressure felt in their minds. For cooperation games, a greater focus was put on the changes in difficulty when increasing the number of players to figure out the essential difference between cooperative and competitive games. The heart rate data that was obtained was then analyzed to determine any significant physiological responses to gameplay and its possible connection to motion in mind theory.

3.5 Chapter Summary

This chapter has detailed the research methodology used in the study, including the data collection methods for different types of games, the design of experiments, and the tools used for data analysis. The methodology was carefully selected to ensure the reliability and validity of the findings, providing a comprehensive understanding of the gaming experiences analyzed in this research.

Chapter 4

Evaluating Random Reward Games

4.1 Chapter Introduction

This chapter outlines the results of analyzing a random reward-based game by applying the motion-in-mind model. The game chosen as the test bed for this dissertation is Genshin Impact, which implements the gacha mechanisms for obtaining new characters or weapons. The number of attempts required to obtain the rare item from the gacha is recorded and studied to determine the relationship between the probability and pity counter in the gacha, helping in designing the ideal gacha game. The possible boundary between gaming and gambling can then be predicted to categorize other random reward games better. The findings will be used to study the significance behind the number of attempts in a random reward game.

4.2 Background of Gacha in Genshin Impact

According to a report by Sensor Tower's latest data, "Genshin Impact" is one of the most successful mobile games ever, having earned more than $4 billion by 2023 [59]. The game was developed by HoYoverse [60], a Chinese video game development company, and was released in September 2020. "Genshin Impact" is a free-to-play open-world action role-playing game that can be played on multiple platforms, including mobile devices, PCs, and gaming consoles. The game's success can be attributed to its immersive gameplay, stunning visuals, and a storyline that keeps players engaged.

Items in Genshin Impact are categorized by rarity, ranging from 1-star to 5-star, with 5-star being the rarest. Characters and weapons are obtainable through the gacha system, where players will use in-game currency to roll and see which items they receive. The currency used to play the gacha is called gems, and it is obtainable by playing the game or purchasing it from the store. Most of the stronger characters and weapons are usually 5-star rarity and are only obtainable through the gacha system. Hence, collecting gems is vital in increasing the combat strength of the players and helping them progress further in the game. The gacha has been very lucrative to the developers, with many crediting the gacha as the reason behind Genshin Impact's success [61].

Genshin Impact also follows the live service model, where update patches are released every six weeks [62]. These patches usually contain new characters, weapons, events, exploration areas, and story progression. As the game follows the F2P model, monetization is focused on the micro-transaction of various items, such as gems for the gacha, character or weapon enhancement materials, and skins. There are also subscriptions to a daily pass for gems and a battle pass, which rewards players with items based on their achievements in the game.

The gacha system in Genshin Impact is called "Wish," and it involves the player spending 160 gems to gamble for an opportunity to obtain a rare character or weapon with rarity ranging from 3-star to 5-star. The higher the number of stars, the more powerful the character or the weapon. 5-star characters and weapons are only obtainable through the gacha, and the odds of obtaining one 5-star character are infinitesimally small at 0.6% while 5-star weapons are at 0.7% [63, 64].

Genshin Impact has three different gacha types: Character Event Wish, Weapon Event Wish, and Permanent Wish. Players use the terminology "banner" to refer to different gacha. Two of the three banners available are time-limited, where the featured item in the gacha is only available for three weeks. The permanent wish is the least popular gacha banner, as the contents within this banner will always be available, making it less of a priority for players.

To participate in the gacha, players must use gems that can be obtained by playing the game daily or during events. However, the rate at which gems are earned is slow, so players must collect and save them in order to play the gacha. Since 5-star characters and weapons are often only available for a limited time, it can be difficult for players to acquire the necessary gems in time. Consequently, some players opt to purchase gems directly from the in-game store using real money. Figure 4-1 below shows the bundles of gems that are sold in the store. Buying the most expensive bundle (US$99.99) is the most worthwhile in terms of money spent per gem (US$0.012 per gem vs US$0.016 per gem in the cheapest bundle). Each attempt at the gacha can be estimated to cost about US$2 as it takes 160 gems for one go. Please note that the prices mentioned in this dissertation reflect regular, non-promotional rates.

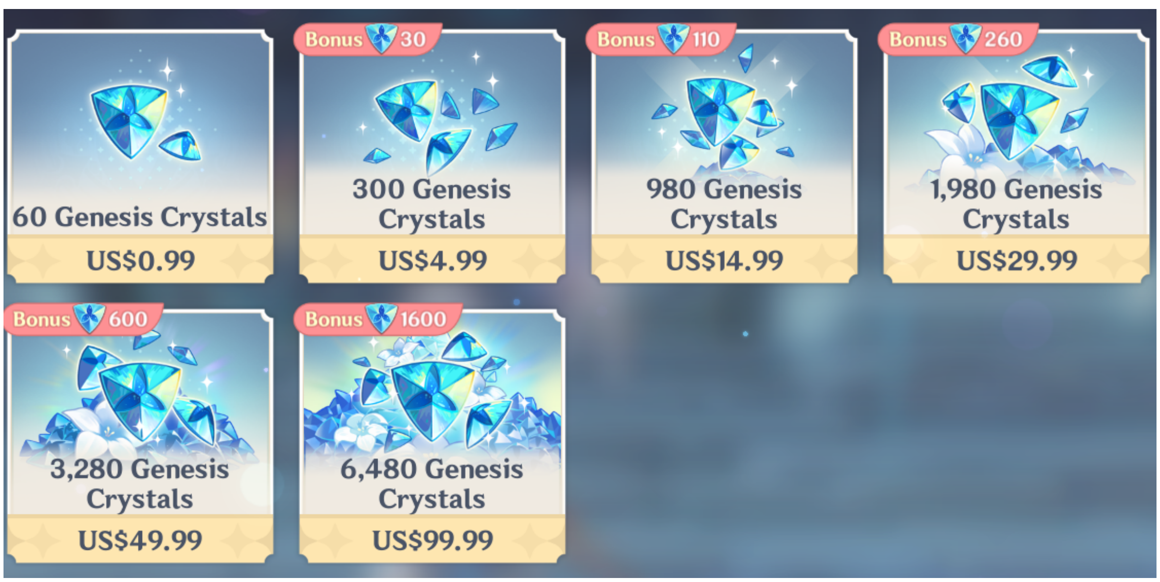

Figure 4-1: Screenshot of the price of gem bundles in Genshin Impact (2023), image courtesy of Hoyoverse

On average, we expect it would take about 166.7 attempts to obtain one 5-star character as the odds of receiving one is 0.6%. Hence, players would have to spend about US$333 to get just one 5-star character. However, it could be possible that a player would be extremely unlucky and not obtain any 5-star characters even after spending all that money. Therefore, Granblue Fantasy introduced the "pity system" in 2016 to guarantee the reward if the player is exceptionally unlucky [28]. The pity system immensely helped create a ceiling price for the gacha and has been quickly adopted by most gacha games today, with the specific parameters of the system being tweaked slightly for each game.

The pity system in Genshin Impact is designed so players will always obtain a 5-star item if they have yet to receive one until the previously set cut-off point. For example, the character banners have their pity counter set at 90, where players will always get a 5-star item if they have yet to obtain one after 89 attempts at the gacha. On the other hand, weapons have a pity counter slightly lower at 80. The pity system helped lower the price of obtaining a 5-star character from the previously mentioned US$333 to only US$180 in the worst-case scenario.

To effectively control their expenses and determine their current pity status in a gacha game, players must keep track of their previous gacha attempts. Although the game provides a gacha history, it only displays the past six months' history. Since Genshin Impact was launched in September 2020, many of the records for earlier gacha attempts are no longer accessible. Therefore, many players use external apps to record their gacha spending and outcomes.

4.3 Data Collection and Analysis

Data collection for this research was done by collecting actual play data of the gacha from Genshin Impact recorded using Genshin Wish Export [1], an open-source external application created by a fan to record and visualize the gacha history. Table 4.1 shows a summary of the gacha history recorded using the application. This study will only focus on the Character Event Wish, as this is the most popular event banner featuring the latest characters. Based on Table 4.1, it could be observed that the total number of pulls done in the Character Event Wish is 4,632 times, more than double of the Weapon Event Wish and Permanent Wish banners combined, which are 1,793 and

[1] available on `https://github.com/biuuu/genshin-wish-export`

662 times, respectively.

Table 4.1: Summary of gacha wish history recorded from player

Banner type	Wish Events		
	Character	Weapon	Permanent
Total Pulls Made	4632	1793	662
Pity counter	90	80	90
Total 5-star obtained	75 (1.6%)	35 (2.0%)	11 (1.7%)
Total 4-stars obtained	608 (13.1%)	267 (14.9%)	81 (12.2%)
Total 3-stars obtained	3949 (85.3%)	1491 (83.2%)	570 (86.1%)
Average N	61.5	51.11	57.1

The motion in mind measures were used to analyze the game's progress to understand its entertainment value. In a gacha game, "winning" could be generalized as the moment the player receives the rare item (reward). Hence, the reward frequency N for Genshin Impact would be the number of attempts required to obtain the 5-star item, which is the highest rarity in the game.

In Genshin Impact, the probability of obtaining a 5-star character is 0.6%. In the worst-case scenario, players will get one 5-star character after 90 attempts at the gacha. On average, it takes $\approx$ 61.50 attempts to get a 5-star character from Genshin Impact's gacha feature. The luckiest moment for the player in Table 4.1 was just five attempts, while the unluckiest needed 83 attempts (refer Table 4.2).

Table 4.2: Motion-in-mind measures for average, luckiest, unluckiest and worst-case based on gacha history

	Goal G	Total attempts T	Velocity v	Mass m	GR	AD
Average	1	61.50	0.016	0.984	0.023	0.030
Luckiest	1	5.00	0.200	0.800	0.283	0.363
Unluckiest	1	83.00	0.012	0.988	0.017	0.022
Best-case	1	1	1	0	1.41	1.817
Worst-case	1	90.00	0.011	0.989	0.016	0.020

[1] Game's Refinement (GR) measure [2] Game's Addictive (AD) measure

Table 4.2 shows that luck has an influence on GR, AD, and v values, which in return indicate the player's success. The minimum velocity is $v = 0.011$, and the maximum is $v = 1$, indicating that the player never loses thanks to the implementation of the pity system. This could explain the reason behind the addiction to gacha.

In the motion-in-mind framework, game difficulty or challenge is represented by mass m and success rate by velocity v. In gacha games, $m \leq v$ only when getting a single 5-star character from one attempt ($m = 0, v = 1$) or two attempts ($m = v = 0.5$). In all other cases, m is significantly larger than v, making winning in gacha games an ordeal due to the low odds of getting a 5-star character.

The ideal zone for the AD measure is where $AD \in [0.045, 0.06]$, where the total number of attempts for the gacha in the Genshin Impact within the range of $T \in [30, 40]$ to be most attractive. Lowering the 5-star pity from 90 to 40 would achieve this. However, it is a complex decision that could affect the game's economy. For instance, pulling one gacha is about \$1.98[2], which can add up to a whopping \$178.22 in the worst-case scenario. Reducing the pity from 90 to 40 may cut the cost to \$79.21, but it could make the 5-star characters feel less valuable to players.

Gao stated that people should feel exceedingly engaged and addicted when $GR = AD$ [65]. This condition is caused by the fact that the GR sophisticated zone can entertain the player, and the high AD value is associated with the feeling of surprise and unpredictability. The ratio between GR and AD can also be expressed as ϕ (see (4.1)), which can be calculated using (2.1) and (2.2). In gacha games, G represents the number of 5-star character obtained, while T represents the total attempts required, can also be equated to the reward frequency N. Subsequently, ϕ will always be a constant value when analyzing gacha games without the influence of the number of attempts T as the T cancels out during division of GR and AD. Hence, a gacha game with $T = 5$ value still has the same ϕ as a game with $T = 55$ or $T = 200$. Hence, we conjectured that $\phi = 0.78$ is an ideal peak for gacha games.

$$\phi = \frac{GR}{AD} = \frac{\sqrt{2}}{\sqrt[3]{6}} = 0.78 \tag{4.1}$$

When $\phi \leq 1$, games exhibit a higher degree of randomness and unpredictability,

[2] It costs about \$100 to purchase 8080 gems, and it takes 160 gems to pull one gacha.

characterized by a larger AD compared to the GR measure. In this context, ϕ represents a measure of predictability and control within the game mechanics. Gacha games and other games of chance are designed with a lower ϕ to emphasize their inherent unpredictability and the element of surprise for players. This low ϕ value reflects a system where outcomes are significantly influenced by random events rather than player skill or strategy.

In gacha games, for instance, players often spend real or virtual currency to receive a randomized reward, which can range from common items to rare and highly coveted ones. The unpredictability is a key factor in their appeal, as it creates a sense of excitement and anticipation with each purchase or pull. This randomness can lead to significant variance in player experience and satisfaction, as some players may receive valuable items quickly, while others may not, driving repeated engagement (addiction) and spending in hopes of achieving better outcomes.

Furthermore, the low ϕ in these games can lead to heightened emotional responses, both positive and negative. The thrill of unexpectedly receiving a rare item can be exhilarating, while the frustration of continuous common rewards can drive players to spend more in pursuit of desired items. This dynamic is a deliberate design choice to enhance player retention and monetization, leveraging the psychological impacts of chance and variability.

Figure 4-2 shows the trend of the reward frequency N (number of attempts) over all the gacha attempts recorded in Table 4.1. The number of attempts required varies over each subsequent character obtained with a random up-and-down motion. Each point on the graph shows that it took N attempts to get that 5-star character. For example, we can observed from Figure 4-2 that the first 5-star is obtained after 83 attempts, while the next 5-star is obtained after 75 attempts. A lower N value signify that the player was really lucky. This randomness creates a roller-coaster effect within players, making the game feel more engaging and entertaining to players. Perhaps the reasons for enjoying gacha are similar to that of a roller coaster.

Previous research on roller coasters from 1976 to 2016 showed the evolution from focusing purely on thrill into focusing on an exciting ride experience [66]. The key to a

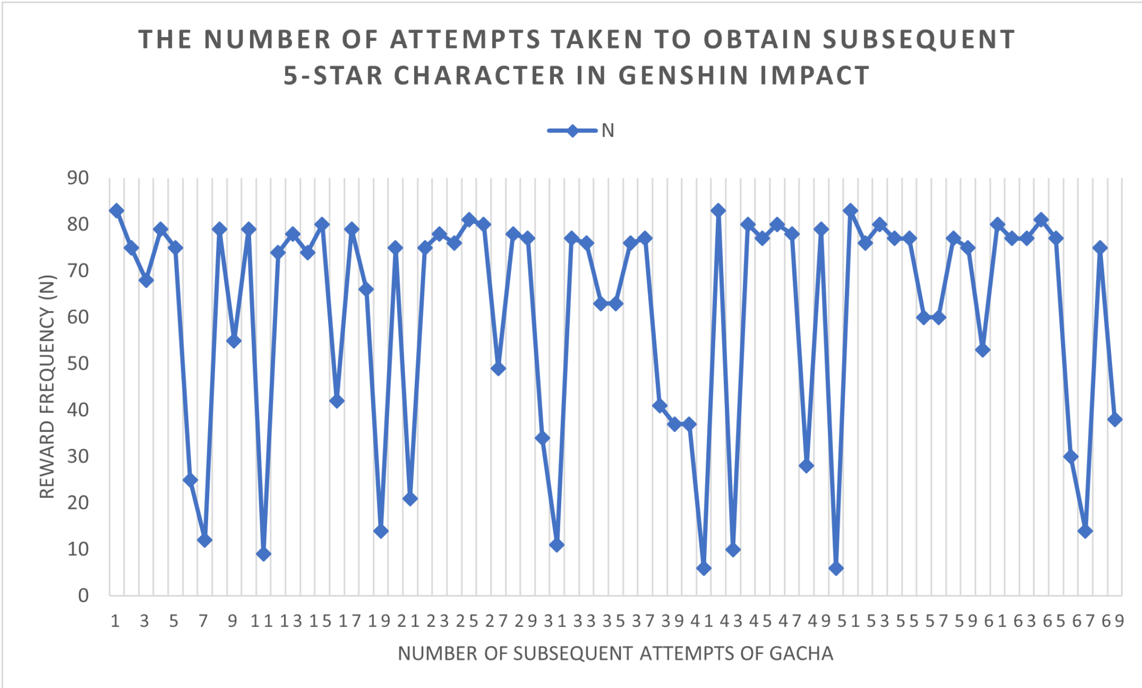

Figure 4-2: Trend of reward frequency N across subsequent gacha attempts

roller coaster's design is to ensure the highest safety under high speed by regulating the roller coaster's height, velocity, and acceleration, ensuring that riders can withstand it. The ever-changing acceleration and forces trigger the fight or flight responses in our bodies, releasing adrenaline or dopamine, causing people to feel excitement and enjoyment from a roller coaster ride [67, 68].

The value of N can indicate whether players are lucky or unlucky in the game. A lower N suggests that players are lucky, while a higher N suggests they are unlucky. The pattern from Figure 4-2 shows as if the game purposely tries to give specific periods of luck (lucky phases) to entice the player and a cooling down period to allow the player to take a breather before the next burst of luck. Players are never always lucky and never constantly unlucky, creating a sense of unpredictability and anticipation when playing the gacha. Giving players too many 5-stars would cause them to feel less valuable while giving too little would frustrate them. Hence, developers should experiment with the pity and odds of gacha thoroughly to ensure maximum player engagement.

Player retention will also be increased due to the pity mechanism of gacha games.

Players who know they will obtain a 5-star item soon will log in and play the game daily to ensure they earn sufficient gems for attempting the gacha. Live service games prioritize ensuring player retention by implementing various mechanics such as daily quests, daily login rewards, and other limited-time event rewards that are only obtainable if players check in to the game often.

Gacha is a purely stochastic game, as players do not need any skills to play them. It is possible to generalize that "skill" in gacha games would be the number of resources (money) the player is willing to spend. Players who spend a significant amount of money in the game are often known as "whale" players [69]. A whale player who spends thousands of dollars would definitely obtain more 5-stars than other players as they can attempt the gacha more often. However, the average number of attempts to get a 5-star does not vary much as we know that gacha games implement some mechanism to ensure players are never constantly lucky.

In order to increase players' emotional attachment to rare items, the frequency of lucky phases should be adjusted as it is crucial that these phases don't happen too frequently or infrequently. By doing so, players will assign a greater personal value to these items, resulting in a more meaningful connection with the game.

4.4 Border between Gaming and Gambling

The rise of gacha games in the mainstream has blurred the distinction between gambling and gaming, underscoring the importance of establishing a clear demarcation between the two. This demarcation is essential not only to accurately classify and rate video games but also to safeguard younger audiences from potential exposures to inappropriate content.

Based on Conjecture 1, we can estimate the gravity in mind using the root of reward frequency $\sqrt{N}$. Gambling and lotteries have high reward frequencies due to the complete stochastic nature of the games. Although the value of the reward are high, games of gambling in nature would have higher gravity in mind due to scarcity of wins. Hence, we can hypothesise that stochastic games would have a higher gravity in mind while games that require player skills result in a lower gravity in mind.

By re-purposing Figure 2-1, we could plot the gravity in mind to examine the exact border between gambling and gaming. Motion in mind states that velocity (success rate) in games can range between 0 and 1 due to the zero-sum assumption, as shown in Equation 2.3. Zero-sum games reflect the perception that one party's gains are necessarily offset by another party's losses, and both parties have all relevant information to make decisions. However, the true odds in certain gambling and lotteries are often hidden or explained vaguely, making it difficult for players to make informed decisions. Hence, we make an assumption that gambling-inspired games and lotteries are not zero-sum games, and thus, its velocity would not be between zero and one.

Line $y_0 = t$ from Figure 2-1 could also be expressed as $y_0 = vt$, where $v = 1$. As this would be the limit for the velocity, the intersection between y_0 and gravity in mind y_4 as shown in Equation 4.2 would give us the border between gambling and gaming. Figure 4-3 shows the intersection of y_0 and gravity in mind y_4, depicting the border between gambling and gaming.

$$y_4 = \sqrt{N} \quad \text{where} \quad N = \frac{T}{t} \quad \text{and} \quad T = \frac{2}{a} \tag{4.2}$$

The border between gambling and gaming as shown in Figure 4-3 can be expressed as y_{04} which is the cross point between lines y_0 and y_4, expressed in Equation (4.3). Assuming that $GR = 0.07$, we conjecture that a game is considered gambling in nature when the gravity in mind $g \geq 7.4$ or reward frequency $N \geq 54.76$.

$$y_{04} = \sqrt[3]{\frac{2}{a}} \tag{4.3}$$

Conjecture 3 *The border between gambling and gaming can be estimated using* $\sqrt[3]{\frac{2}{a}}$*.A game located within the GR zone of 0.07 and 0.08 can be considered gambling in nature if the gravity in mind* $g \geq 7.4$ *or reward frequency* $N \geq 55$*.*

As gacha in Genshin Impact has $N = 61.5$ and $g = 7.8$, we can categorize the gacha as gambling in nature. This could explain the reason why people might get addicted to gacha games easily and occasionally overspend.

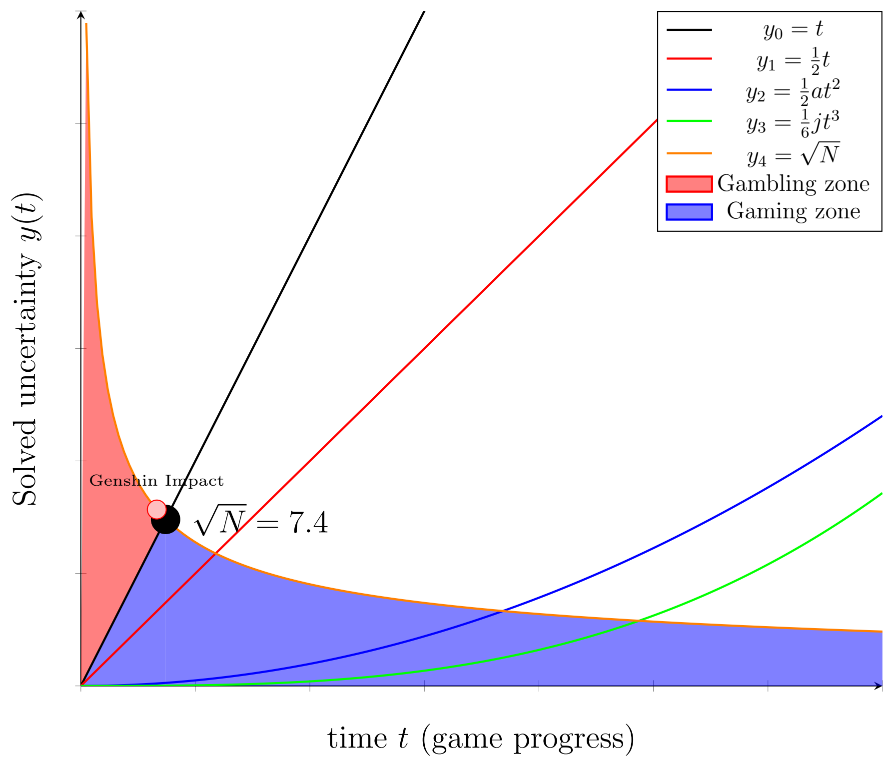

Figure 4-3: The depiction of the border between gambling and gaming

4.5 Designing an Ideal Gacha Game

The probability of obtaining the rarest item from a gacha is often relatively low, making it difficult to get it in a reasonable number of attempts. The pity system acts as a safety net for players by providing a guaranteed shot at obtaining them. Some games have a pity system that increases the probability of obtaining rare items after several unsuccessful attempts. For example, Genshin Impact has a pity of 90, where players are guaranteed to receive the highest rarity item (5-star) if they have yet to obtain one. Several games achieve this by gradually increasing the probability of obtaining the item until it reaches 100%, while other games instantly increase the probability to 100%.

For example, Alchemy Stars has a base probability of 2% to obtain a 6-star item. After 50 unsuccessful attempts, the probability will gradually increase by 2.5%, achieving 100% odds on the 90th attempt [70]. On the other hand, the developers of Genshin Impact did not reveal how they increased the probabilities of the item. Still, many users speculated that the game has a hidden mechanism that boosts the probability after 70 unsuccessful attempts. This was dubbed as the soft-pity system by online forum users, with many documenting how most players obtain their 5-star item between 70 to 80 attempts [71].

Other games implement a pity called the "spark" system. This was first introduced by Granblue Fantasy back in 2016 [28], where players obtained an item called spark when they attempted the gacha. Players can then exchange this accumulated spark to claim the item with the highest rarity directly from the gacha. The pity counter for these games is denoted by the number of sparks needed to exchange for the item. In the case of Granblue Fantasy, players needed 300 sparks to exchange for the item from the shop. Hence, the pity for Granblue Fantasy is listed as 300.

Games that utilize the spark system often have their pity counter much higher than other games. This is due to the probability of obtaining the item are often much higher. However, the problem arises when there are multiple items of high rarity available. Let us look at an example case where the probability of obtaining one 5-star item is 10% and there is a total of 50 different 5-star items in that gacha. A player who wants a specific item out of the 50 that are available will have to battle two odds: the 10% odds of getting the 5-star item and the 1/50 odds of receiving the item they wanted, making the probability infinitesimally low at 1/500.

The spark system was introduced before the probability altering pity system. Many players preferred the latter version of pity as it feels less overwhelming due to its generally lower pity counter. However, both systems are still widely used in popular gacha games today. The table below shows several popular gacha games categorized by its pity system.

Games that utilize the spark system often have their pity counter much higher than other games. This is because the probability of obtaining the item is usually much higher. Most players often times obtain the item they wanted much earlier than the pity, making the spark system act as a "bonus" instead of a safety net as they could get another copy of the item when they reach the pity. However, the problem arises when multiple items of high rarity are available. Let us look at an example case where the probability of obtaining one 5-star item is 10%, and there is a total of 50 different 5-star items in that gacha. A player who wants a specific item out of the 50 available must battle two odds: the 1/10 odds of getting the 5-star item and the 1/50 odds of receiving the item they wanted, making the probability tiny at 1/500.

The spark system was introduced before the probability-altering pity system, offering players a choice in their gaming experience. Many players found the latter version of pity more manageable, as it features a generally lower pity counter. However, both systems continue to be widely used in popular gacha games today, giving players the power to choose the gaming experience that suits them best. Table 4.3 categorizes several popular gacha games based on their pity system, in addition to the probability of obtaining the highest rarity item and the price per attempt.

It can be observed that the pity counter is generally higher when the probability is high, and conversely, the pity counter is set lower when it is more difficult to obtain the character. This is to ensure that players have a safety net when playing the gacha where they will eventually win if they are extremely unlucky. However, it also ensures that players do not win too often as it will reduce the perceived value of the gacha to players due to over-saturation of high rarity characters.

Gacha games that increase the probability of the items can guarantee the players obtain a specific or a random rare item. In Table 4.3, we can observe that the games that increases the probability to guarantee a specific item have a significantly higher pity than those that guarantee a random item. This strategic design of the pity system by developers is intriguing, as it ensures that players do not obtain the items too easily, thereby maintaining the subjective value of it towards the player.

We feel that both the probability and price of the gacha contribute to how the pity counter is set. In order to find the correlation between the pity and the price with respect to the probability, we used multi linear correlation analysis.

We believe that the pity type which increases the probability of a specific item cannot be compared with those that guarantees a random rare item. The certainty

Table 4.3: Summary of probability, price per attempt, pity counter and pity type of various gacha games

Game	Probability in %	Price in USD	Pity Counter	Pity Type
Alchemy Stars	2.00	2.86	90	Increasing Probability
Arknights	2.00	1.80	99	
Bang Dream	3.00	2.27	50	
Cookie Run: Kingdom (Epic)	2.80	1.92	100	
Dragalia Lost	4.00	2.29	100	
Dragalia Lost Gala	6.00	2.29	60	
Fire Emblem Heroes	3.00	2.14	120	
Genshin Impact	0.60	1.98	90	
Girls Frontline: Neural Cloud	3.60	2.31	60	
Honkai Impact 3rd	2.25	3.46	100	
Honkai Star Rail	0.60	1.98	90	
Tears of Themis	1.60	2.23	100	
Tower of Fantasy	0.75	1.93	80	
Wuthering Waves	0.80	1.98	80	
Azur Lane	1.20	1.35	200	Increasing Probability for a Specific Item
Counter:Side	3.50	1.03	150	
Dangeki Bunko: Crossing Void	1.50	1.82	91	
Epic Seven	1.25	2.63	121	
Fate/Grand Order	1.00	1.44	330	
Girls Frontline: Neural Cloud	3.60	2.31	180	
Punishing Gray Raven	0.50	4.10	60	
Alice Fiction	2.50	2.40	200	Spark
Azur Lane	1.20	1.35	500	
Bang Dream	3.00	2.27	300	
Blue Archive	3.00	1.62	200	
Dangeki Bunko: Crossing Void	1.50	1.82	240	
Dissidia Final Fantasy	5.00	2.06	150	
Dragon Ball Z: Dokkan Battle	10.00	1.50	500	
Dragon Ball Z: Dokkan Battle v2	10.00	1.50	200	
Granblue Fantasy	3.00	1.00	300	
Guardian Tales	2.00	1.91	300	
Hatsune Miku Colorful Stage Free	3.00	2.29	100	
Hatsune Miku Colorful Stage Paid	3.00	2.29	50	
Idolmaster Cinderella Girls Starlight Stage	3.00	2.22	300	
Idolmaster Million Live	3.00	2.22	300	
Idolmaster Shiny Colors	2.00	2.39	300	
Love Live School Idol Festival 2	3.00	2.08	250	
Love Live SIF Allstars	5.00	2.43	250	
Nier Reincarnation	2.00	2.59	200	
Nikke	4.00	3.87	200	
Pokemon Masters EX	10.00	2.45	400	
Princess Connect! Re:Dive	2.50	2.18	300	
SinoAlice	3.00	2.10	150	

provided by guaranteeing a specific item makes it comparable to the spark pity type. Hence, the pity type that increases the probability of a specific item will be analyzed together with the spark type.

The multiple linear regression results indicated a weak collective non significant effect between the probability, price per attempt, and pity counter for gacha games with increasing probability.

The overall regression is right-tailed, $F(1, 12) = 1.11$, $p - value = 0.312$. Since $p - value > \alpha(0.05)$, we accept the H_0. Price was ignored as it is less significant as a predictor for pity when compared to the probability. The R-square (R^2) equals 0.085, which means that the probability explain 8.5% of the variance of pity. The adjusted R-square equals 0.009. The coefficient of multiple correlation (R) equals 0.192. It means that there is a weak correlation between the predicted data and the observed data.

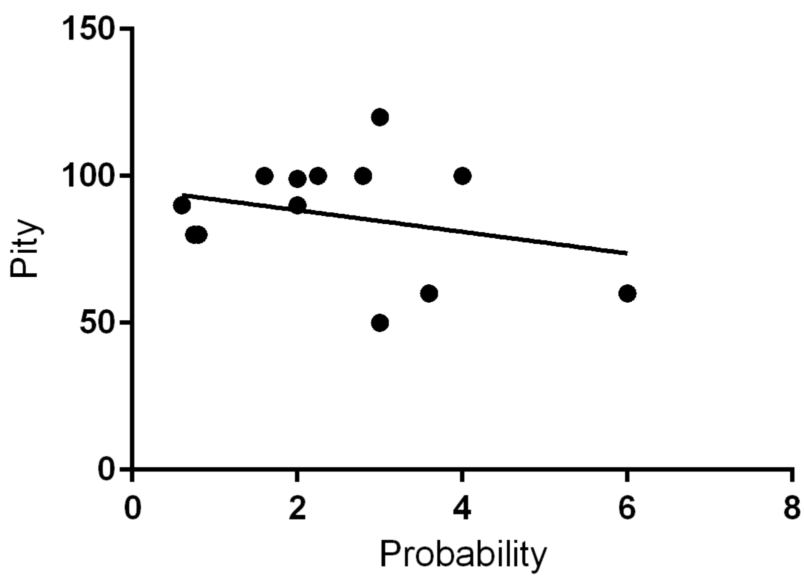

Figure 4-4: Scatter plot of the pity against the probability gacha games with increasing probability pity from Table 4.3

Figure 4-4 shows the scatter plot of the pity against the probability of gacha games with increasing probability pity listed in Table 4.3. The pity counter for this pity type can then predicted using the equation in Equation (4.4).

$$Pity = 95.7 - 3.7(Probability) \tag{4.4}$$

Next, we analyzed the remaining two pity types together. The multiple linear regression results indicated a weak collective non significant effect between the probability, price per attempt, and pity counter for gacha games.

The overall regression is right-tailed, $F(1, 27) = 3.83$, $p - value = 0.061$. Since $p - value > \alpha(0.05)$, we accept the H_0. Probability was ignored as it is less significant as a predictor for pity when compared to the price per attempt. The R-square (R^2) equals 0.124, which means that the probability explain 12.4% of the variance of pity. The adjusted R-square equals 0.09. The coefficient of multiple correlation (R) equals 0.352. It means that there is a weak correlation between the predicted data and the observed data.

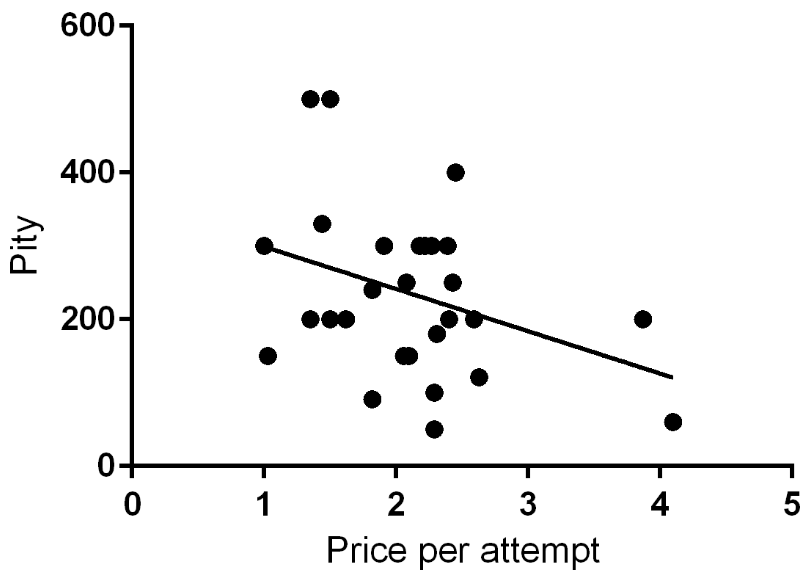

Figure 4-5: Scatter plot of the pity against the price per attempt of gacha games with specific item guarantee and spark pity system from Table 4.3

Figure 4-5 shows the scatter plot of the pity against the price per attempt of gacha games with specific item guarantee and spark pity system pity listed in Table 4.3. The pity counter for this pity type can then predicted using the equation in Equation (4.5).

$$Pity = 356.9 - 57.6(\text{Price per attempt}) \tag{4.5}$$

When comparing the two equations obtained from the linear regression, we found that one showed the significance of the probability towards the pity counter while the other showed that the price per attempt was more significant than the probability.

We found that gacha games with increasing probability of obtaining a random item have its pity at a maximum of 95.7 based on Equation (4-4) as the probability will always be greater than 0. On the other hand, Gacha games with spark pity types have their maximum pity at 356.9 based on Equation (4-5) as the price could not be negative.

An interesting observation can be made that the price per attempt is more significant for gacha games with spark-type pity systems, as the pity counter is generally higher. Hence, developers should pay more attention to the price per attempt of gacha games when the pity counter is higher to ensure players do not feel too frustrated.

To answer RQ2, we feel the ideal pity counter for a gacha game should be based on the success rate. Although the price per attempt is important in maintaining the economy of the game, its not too significant in deciding the pity counter of the game with a lower pity counter.

Conjecture 4 *The ideal pity counter when focusing only on gacha games with increasing probability of obtaining a random rare item can be estimated using* $95.7 - 3.7(\textit{Probability})$*. The pity counter for gacha games with sparks systems then can be estimated using* $356.9 - 57.6(\textit{Price per attempt})$*.*

In order to create a fair environment for players, developers of gacha games should ensure that the price of each attempt is regulated in accordance with the pity system and the probability of obtaining the rare items. For a gacha with a higher pity counter, say 300, the cost of each attempt should be cheaper than Genshin Impact (US$2) if the probability is kept the same at 0.6%, as the total price for the worst-case scenario would be too expensive otherwise.

Motion in mind suggested that a gacha game would be most exciting if the pity counter were between 30 and 40. However, the pity formula obtained from linear regression in Conjecture 4 does not match as the pity of most games analyzed appears to be much higher than what we expect. We believe the pity counter was intentionally higher to maximize player retention over entertainment. A higher pity would ensure that players would play and grind the game longer to collect sufficient resources or spend money to attempt the gacha. Both options are beneficial to developers as they help increase the game's longevity. In 2022, Dragalia Lost shut down its servers, with many speculating that the game's revenue was the main reason behind its decline [72]. Many users online felt that the gacha from the game was too generous to players, reducing the need for players to spend money on the game [73]. Hence, the pity formula we proposed can be considered ideal in the eyes of the developers, not the players.

4.6 Significance of the number of attempts η

A game is truly engaging when the outcome is unpredictable in a fair game scenario. As the act of playing a game is equated to solving the uncertainty of its outcome, it would be necessary in some cases for the player to make several attempts at the game to receive sufficient confidence for the outcome of the game. Hence, it is also important to consider the number of attempts made and its significance throughout the game.

Consider a notion of the potential reinforcement energy as a measurement of objectivity of the outcome of the thing under consideration. Potential Reinforcement Energy PRE of a given event, characterized by its velocity v (where $N = 1/v$), is defined as a function of the number of trials η, which is determined by Eq.4.6.

$$PRE = \eta T/N^2 \tag{4.6}$$

As conjectured in Conjecture 1, the magnitude of gravity of play gives us an extraordinary feeling in the space with larger gravity compared to the magnitude which we were comfortable with previously. Likewise, we may feel comfort by the standard gravity in mind, denoted as a_0, whereas uncomfortable or extraordinary by the different (larger) degree of gravity in mind, denoted as a.

We can then define the magnitude of extraordinary experience MEE as the ratio of extraordinary gravity in mind over the standard one, determined by Eq.4.7.

$$MEE = \frac{a}{a_0} = \sqrt{N} \tag{4.7}$$

Figure 4-6 illustrates the potential reinforcement energy PRE and magnitude of extraordinary experience MEE with a focus on the cross points between the different lines for PRE where η is 1, N and $N/100$, respectively. The highlighted region shows the intersections for GR zone between the ranges of $[0.07, 0.08]$.

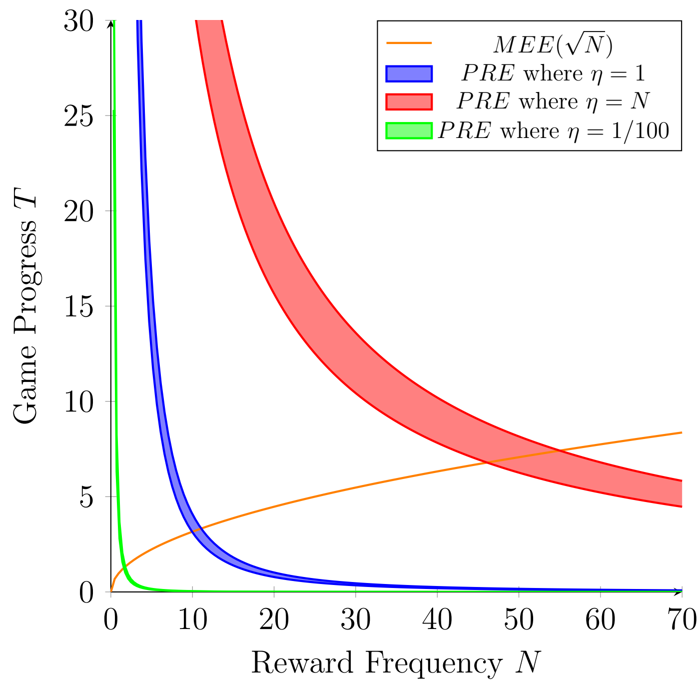

Figure 4-6: The depiction of Magnitude of Extraordinary Experience (MEE) and its relationship with Potential Reinforcement Energy (PRE) of varying number of attempts η for events located within GR zone

The three cross points between MEE and PRE signifies three different scenarios of games:

- When $\eta = N$, it signifies that the game has to be played N times in order to be confident of the outcome of the game. This is apparent in games of chance, where if the probability of winning the game is 1% ($v = 0.01, N = 100$), it would take 100 attempts on average to ensure that you win once. Gacha games implement this where players have to attempt the gacha for N times until they reach the pity and obtain the rare item, where $N = 61.5$ based on the data collected in Table 4.1. Hence, games with $N > 45$ requires at least N attempts to ensure players engagement towards the outcome of the game.

- $\eta = 1$ shows the cross point between PRE and MEE happens when $N \approx 10$. Previous work by Gao Naying showed how imperfect information games like Mahjong and Doudizhu have their reward frequencies at 8 and 9, respectively [65]. This cross point shows the scenario of imperfect information games which incorporates chance and skill, contrasting to games of pure chance as shown in the previous cross point where $N > 45$. Hence, players often time only need to play games with $N \approx 10$ once to be fully engaged and confident throughout the outcome of the game.

- The final cross point shows the scenario for perfect information games like Chess and Go where $N \approx 2$. These games are more skill oriented with a lesser influence by chance compared to the previously listed games. However, to achieve this cross point, players would need to play the game 1/100 times (1% of the game progress), which is harder to imagine compared to the previous two cases. We conjecture that grand-master level players often can predict the outcome of a game based on the opening moves. As such, we feel that $\eta = 1/100$ signifies the opening moves of a game in a pefect information skill-based game.

4.7 Chapter Summary

This chapter analyzed the reward frequency in the gacha mechanics of Genshin Impact, revealing that it took an average of 61.5 attempts to obtain a 5-star character. Based on these findings, the threshold between games of chance and gambling was identified at around $N = 55$, facilitating a clearer distinction between the two. An ideal gacha game can be designed using the linear regression formula derived from comparing various popular gacha games currently on the market.

Utilizing our findings from this chapter, we can enhance the entertainment value of gacha games while ensuring fairness to both players and developers. Additionally, games were categorized based on their reward frequency by analyzing the intersection points between potential reinforcement energy PRE and the magnitude of extraordinary experience MEE concerning the number of attempts made η. This categorization helps in understanding the dynamics of player engagement and satisfaction in relation to the reward frequency in gacha games to help improve games in the future.

Chapter 5

Pressure and Difficulty in Games

5.1 Chapter Introduction

This chapter outlines the formulation of a novel metric of measurement in motion in mind: pressure. Pressure or stress is a commonly used term when considering why players quit a game, making it paramount to learn more about it to improve future games. Several games will be analysed to make comparisons between them to determine the significance of pressure as well as its formulation with respect to the number of players in a game. Key differences between previously formulated mass depicting the difficulty of the game and the newly proposed pressure should be highlighted.

5.2 Formulating Pressure in Mind

Pressure can be evaluated in two ways, depending on the medium of matter (solid or fluid) as shown in Eq. (5.1), where P is the pressure, F is force, A is the surface area, ρ is the. When calculating the pressure in fluids, it is important to take the density of the fluid into consideration. Density can be defined as the degree of concentration or the compactness of the molecules in the object, which could be equated as the ratio of mass to volume.

$$P = \frac{F}{A} \text{ or } P = \rho g h \tag{5.1}$$

We can further simplify the formula for pressure by substituting in gravitational potential energy (U) where $U = mgh$ as shown in Eq. (5.2).

$$P = \rho g h = \rho \left(\frac{U}{m} \right) \tag{5.2}$$

Potential energy in game context (E_p) has been defined in previous works by Akmal et. al. [22] as $E_p = 2mv^2$. Pressure in mind can then be expressed as shown in Eq. (5.3)

$$P = \rho \left(\frac{E_p}{m} \right) = \rho \left(\frac{2mv^2}{m} \right) = 2\rho v^2 \tag{5.3}$$

In the context of games, we could use the concentration of players in the game as the density to obtain the pressure. The density of players would then equate to the number of players divided by the total play area. The play area in a game would be difficult to generalize as different games use different units to measure playable space. For example, sports use meters, board games use squares (or spaces), and video games use pixels.

$$\rho = \frac{\text{Number of players}}{\text{Total play Area}} \tag{5.4}$$

However, it would be possible to make comparisons between similar games. The density could then be expressed as a ratio between the games, eliminating space units. For example, futsal could be compared to soccer as the game rules are similar, while badminton could also be evaluated by comparing the single and double variants.

We predict that pressure in games adds to their difficulty, which involves risk-taking tendencies. A game with high pressure might not necessarily be challenging, but players might take larger risks to achieve goals in the game.

5.2.1 Limitations

The density proposed in Equation 5.4 accounts only for the spatial density of a game concerning the number of players, thus explaining only the spatial pressure experienced by players. However, we believe that there are several other types of pressure in the game, such as temporal (time) pressure and skill-based pressure.

Time pressure arises in scenarios where limited time forces players to act quickly, leading to stress. This type of pressure increases the game's difficulty as players have less time to strategize their next move, potentially resulting in oversights.

Skill pressure occurs when players of varying skill levels are required to play together or against each other. A skilled player often feels more pressure as they bear the responsibility of compensating for their teammates' mistakes and meeting the high expectations placed on their performance.

5.3 Findings and Result Analysis

In this section, we will explore different genres of sports and games. The games will then be compared with their alternate or spin-off versions to obtain the density and pressure in games.

5.3.1 Soccer vs Futsal

Soccer is typically played with two teams, each consisting of 11 players. The game is played on a large field measuring up to 120m x 90m. Figure 5-1 illustrates the dimensions of a standard soccer field. However, recognizing that many communities may not have access to such large fields, street soccer was created. Street soccer utilizes small available spaces such as roads, alleys, and indoor rooms as playing grounds. In street soccer, goalposts are generally much smaller compared to traditional soccer. Street soccer later evolved into futsal and gained enough popularity to be recognized by FIFA, leading to the organization of the first Futsal World Cup in 1989.

Futsal is played with only five players on each team on a field measuring 42m x

25m, as shown in Figure 5-2. This is much smaller than a standard soccer field, making it more accessible to most people. The game consists of 2 halves of 20 minutes each, as opposed to the 45 minutes in soccer. Due to the smaller field and fewer players, the game is generally more active than soccer.

Comparing the total area in a soccer and futsal game, we can see that a soccer field is almost nine times larger. As such, let's assume that the ratio of the area in futsal is 1 while the area of a soccer game is 9. Then, the density could be evaluated using Eq. 5.4, giving us 10 and 2.4 for futsal and soccer, respectively.

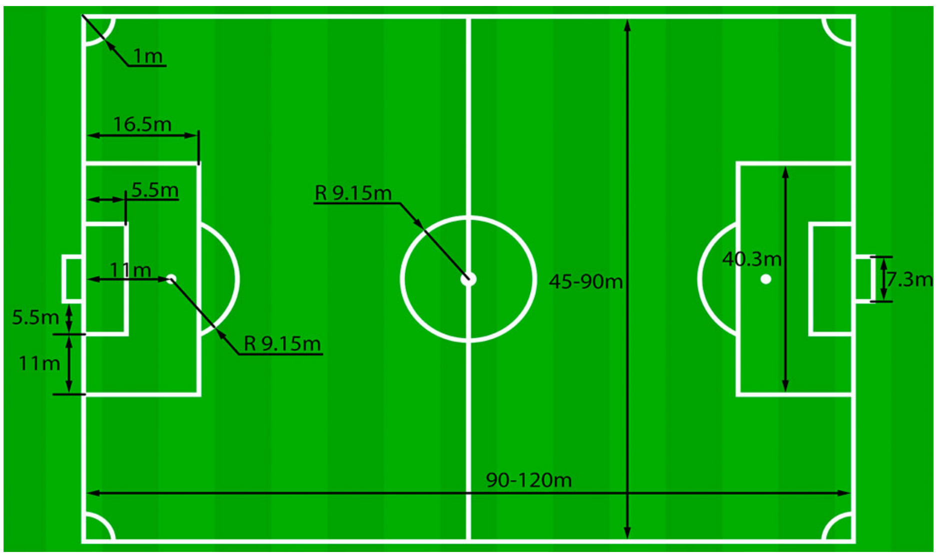

Figure 5-1: Dimensions of Soccer field, from [1]

Table 5.1: Motion in mind values for soccer and futsal

Game	v	m	ρ	**Pressure**
FIFA Futsal 2016	0.359	0.641	10	2.578
FIFA 2018 Soccer	0.281	0.719	2.4	0.379

Based on Table 5.1, soccer appears to be more stochastic than futsal due to its lower velocity v. This makes soccer more exciting and engaging for players and viewers due to its unpredictable outcome. We can also infer that futsal is more skill-oriented than soccer. This could be due to the smaller field size and fewer players, as it encourages the players to perform more passes, skills, and dribbles [74]. Futsal is also faster paced than soccer as the average number of goals per game is 6.77, significantly

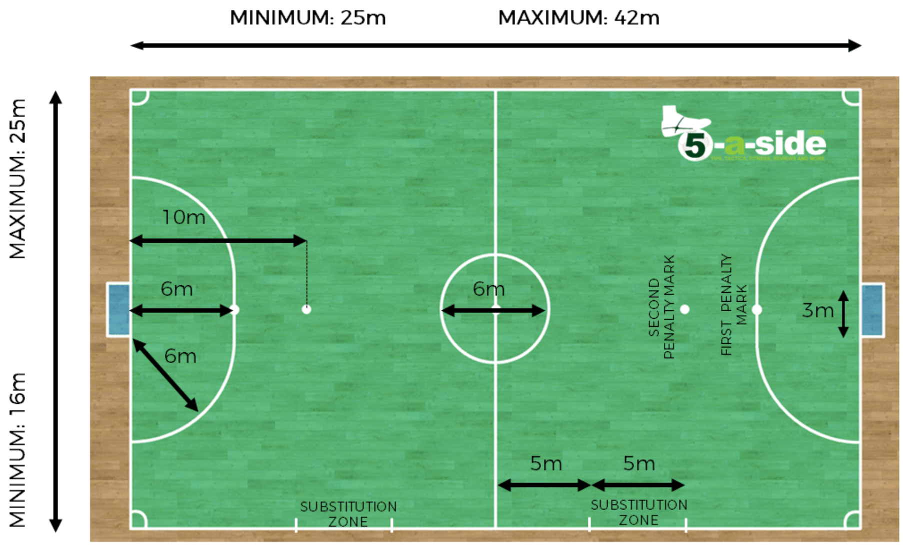

Figure 5-2: Dimensions of Futsal field, from [2]

higher than soccer's 2.64 despite the game duration being only 40 minutes compared to soccer's 90 minutes.

When comparing the pressure levels in futsal and soccer, it's remarkable that futsal experiences nearly seven times the pressure found in soccer. This is likely due to the much higher density of players in futsal, as the field size is significantly smaller than in soccer, leading to players having much lower freedom of movement. The lower freedom causes players to feel pressured to make something happen in the game, which is apparent by the significantly higher average goals in futsal, which, in turn, increases the stakes of the game.

5.3.2 Basketball vs 3x3

Basketball is played by two teams of 5 players, aiming to secure a higher point than the opposing team. There are two baskets on each side of the court; points are scored based on the distance of the throw from the basket when it successfully enters the basket. Figure 5-3 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 game organizers.

3x3 is a variation of basketball, consisting of 3 players on each team playing on a court about 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 recognizing the format and organizing the first-ever 3x3 tournament in 2007. The game lasts only 10 minutes but can end shorter as the winner will be decided based on the first team that scores 21 points.

Comparing the court sizes in 3x3 and basketball, it is simple as 3x3 is simply half of that in basketball. As such, let's assume that the area ratio in 3x3 is 1 while the area of a standard basketball game is 2. Then, the density could be evaluated using Eq. 5.4, giving us 6 and 5 for 3x3 and basketball, respectively.

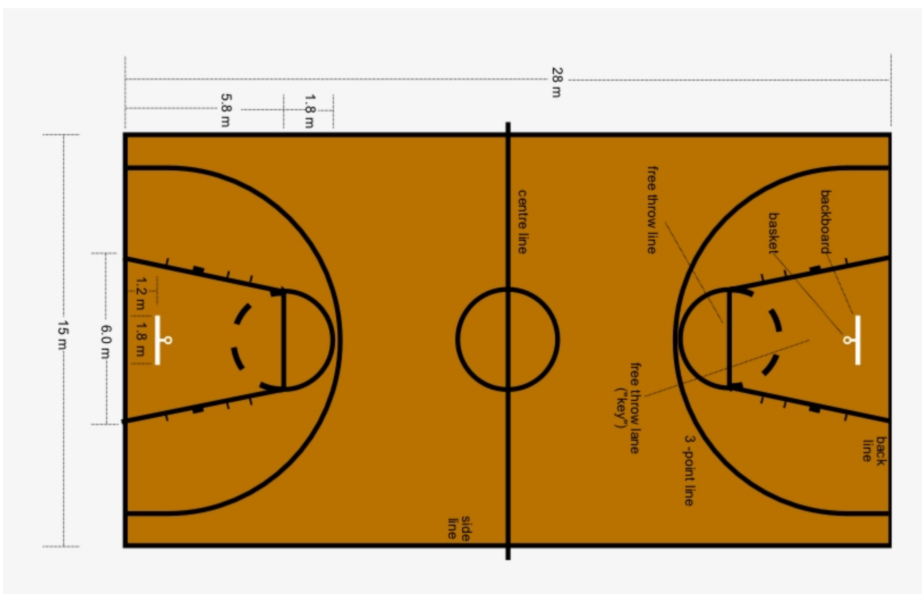

Figure 5-3: Dimensions of Basketball court, from [3]

Table 5.2: Motion in mind values for 3x3 and basketball

Game	v	m	ρ	**Pressure**
3x3	0.476	0.524	6	2.719
Basketball	0.487	0.513	5	2.372

Based on Table 5.2, basketball appears slightly more deterministic than 3x3, although the velocities are pretty close. Contrasting to the case study for soccer, the smaller version of basketball seems to be somewhat more stochastic. However, the trend in pressure is similar to that in soccer and futsal, such that the smaller version of basketball (3x3) has a higher pressure than the standard basketball. The difference is significantly smaller due to the density of players in 3x3 and standard basketball being close.

5.3.3 Singles vs Doubles in Badminton

Badminton is a racquet sport played on a court split into two sides by a net in the middle. Two commonly played formats are singles and doubles, with one or two players on both sides. The court size is slightly bigger for doubles, but other rules are similar to singles. Figure 5-4 shows the dimensions of a common badminton court used for singles and doubles.

The size of the badminton court in doubles is 1.17 times larger than in singles. Using the formula shown in Eq. 5.4, the density for singles and doubles would be 2 and 3.42, respectively. The pressure can then be obtained using Eq. 5.3.

Five categories of badminton matches were analyzed: singles and doubles for men and women and a mixed doubles category with one man and one woman on each side. To ensure that players' skill levels are equal, we collected data on badminton matches played in The Olympics.

Table 5.3: Summary of motion in mind values for Badminton Singles and Doubles

Type	G	T	v	N	ρ	Pressure
Olympics 2016 Badminton Men's Single	20.49	34.31	0.60	1.67	2	1.43
Olympics 2016 Badminton Women's Single	20.64	34.40	0.60	1.67	2	1.44
Olympics 2016 Badminton Men's Doubles	20.23	36.79	0.55	1.82	3.42	2.07
Olympics 2016 Badminton Women's Doubles	20.71	36.09	0.57	1.74	3.42	2.25
Olympics 2016 Badminton Mixed Double	20.91	36.14	0.58	1.73	3.42	2.29
Olympics 2020 Badminton Men's Single	20.43	34.03	0.60	1.67	2	1.44
Olympics 2020 Badminton Women's Single	20.74	32.98	0.63	1.59	2	1.58
Olympics 2020 Badminton Men's Doubles	20.73	35.26	0.59	1.70	3.42	2.36
Olympics 2020 Badminton Women's Doubles	20.51	35.66	0.58	1.74	3.42	2.26
Olympics 2020 Badminton Mixed Double	20.74	35.71	0.58	1.72	3.42	2.31

Table 5.3 summarizes the analysis done on badminton matches held during the 2016 and 2020 Olympics. Throughout both years, singles appear to be more deter-

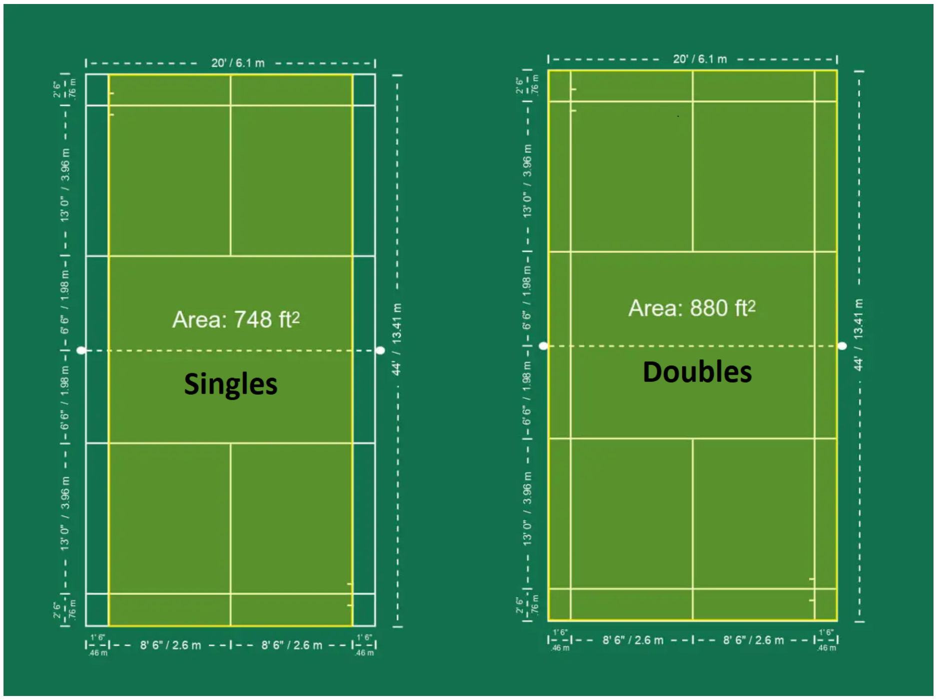

Figure 5-4: Dimensions of Badminton courts [4]

ministic than doubles as they have a higher velocity. Singles often have $v \geq 0.6$ while doubles have $v \leq 0.6$. This conforms to our previous hypothesis, which states that a higher number of players in a game increases the stochastic aspects of the game. In contrast, fewer players make it more deterministic.

Despite the similarity of the rules between singles and doubles, each feels distinctly different, which is apparent in the strategies used in games. The main reason for the difference in strategy stems from the amount of space each player needs to cover. In singles, the player will be solely responsible for the entire court, where they cannot rely on others to retrieve a shot even if they are out of position. In doubles, the player has a partner that can cover areas difficult to reach, opening up the possibility for riskier play styles than singles [4].

The results tabulated in Table 5.3 show the velocity of men's and women's singles across both years are similar to each other with an average of $v = 0.61$. A similar trend can also be seen in men's, women's, and mixed doubles with an average of $v = 0.58$. We conjecture that the similar velocities cause the game to feel somewhat similar to each other for both players and viewers. Singles and doubles, on the other hand, feel different due to their differing velocities, making singles more deterministic than doubles.

Conjecture 5 *Games are categorized by its velocity v and reward frequency N. There is a sense of familiarity when playing different games with similar v and N.*

Table 5.3 shows that doubles have more pressure on players compared to singles. This is mainly due to the higher density in doubles as the velocity is relatively close. As the badminton court in doubles is only 1.17 times larger than singles, this lowers the freedom of movement for doubles, which in turn increases the pressure. This can explain why players in doubles often involve themselves in riskier plays than singles.

5.3.4 Comparing various MOBA game modes

MOBA games often consist of 10 players, divided into two teams of five players, and each team will be placed on 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 three lanes in the game. The areas between the lanes are called the jungle, where computer-controlled enemies (often called jungle creeps) reside. These jungle creeps provide players with additional resources (gold and experience) and aid them in pushing the lanes and ultimately reaching the enemy's base. Figure 5-5 shows the typical 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 various games with minor modifications.

Three popular MOBA games will be studied in this section: Dota 2, League of Legends (LoL), and Smite. Several game modes will be analyzed for each game, each with a standard mode (follows the map structure in Figure 5-5) and other spin-off modes with varying map designs or number of players in a team.

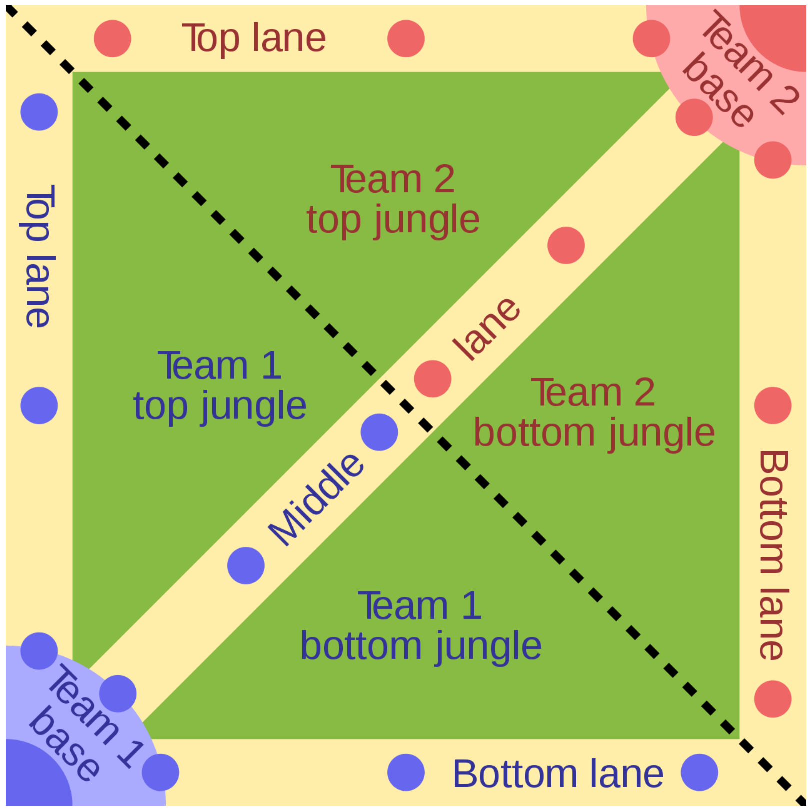

Figure 5-5: Map Structure in MOBA games, from [5]

The objective in a MOBA game is to attack the enemy's defensive structures located in the lanes while also defending your structures from the enemy's forces. As such, let's generalize the number of lanes as the size of the playing field.

Let A be the total area of a lane in a MOBA game. A standard MOBA game with three lanes of five players on each side; then the density would be $\rho = \frac{10}{3A}$. Dota 2's Solo Mid mode has only one lane. Therefore, the density would be $\rho = \frac{2}{A}$. Similarly, we can apply this to the other modes of MOBA games to obtain the density as a ratio to its standard mode. The results are tabulated in Table 5.4.

The mass m and velocity v tabulated in Table 5.4 are weighted averages between the different objectives in a MOBA game. There are various ways for players to gain an advantage over their opponents in MOBA games, namely kills, gold, and experience. Previous work highlighted that obtaining the weightage of each advantage would give an accurate way to evaluate the overall aspect of the game without making general assumptions [58].

Table 5.4: Comparison of density and pressure of each MOBA modes

Game	Mode	Players	Lanes	Density	Mass	Velocity	Pressure
Dota 2	**Captains Mode**	5vs5	3	3.33	0.469	0.531	1.88
	Solo Mid	1vs1	1	2.00	0.37	0.63	1.59
League of Legends	**Summoner's Rift**	5vs5	3	3.33	0.391	0.609	2.47
	Twisted Treeline	3vs3	2	3.00	0.477	0.523	1.64
Smite	**Conquest (Standard)**	5vs5	3	3.33	0.44	0.56	2.09
	Arena	5vs5	1	10.00	0.471	0.529	5.60
	Joust	3vs3	1	6.00	0.392	0.608	4.44
	Clash	5vs5	2	5.00	0.447	0.553	3.06
	Siege	4vs4	2	4.00	0.435	0.565	2.55

Similar to our previous observation, having more players leads to more stochastic games, evidenced by their lower velocity. This pattern appears in each game mode studied in this section. Hence, an appropriate generalization could be inferred, such that increasing the number of players, in turn, increases the unpredictability of a game.

MOBA players often look for three main aspects to satisfy them: competition, a sense of mastery, and teamwork [75]. Players who seek competition will enjoy fast-paced game settings with higher stakes. Hence, we feel that higher pressure is favored for MOBA players, which explains the popularity of the standard modes in Dota 2 and League of Legends. In Smite, however, the standard mode appears to have the lower pressure, while Arena and Joust are the highest. According to [76], Joust is the most popular mode among players, followed by Arena, and finally, Conquest, the standard mode.

5.4 Comparing Pressure and Difficulty towards the Outcome of Games

Pressure is greatly influenced by the density of players in a game, while our previous measure of difficulty (mass m) is dependent on the scoring rate of the game. Larger density signifies that players have a lower degree of freedom in games, giving them fewer choices when making crucial decisions. This increases the risk for players when making their moves. It may not directly influence the game's difficulty as it does not affect the scoring rate significantly. Hence, we conjecture that pressure gives a different sense of challenge to games compared to mass.

When considering mass, a higher mass also shows that the game is more stochastic or chance-oriented. Conversely, a lower mass depicts that the game is more deterministic or skill-oriented. Pressure, on the other hand, only considers the stakes of the game.

Our research has led us to a compelling conclusion. We can express mass m in terms of pressure P and density ρ, as shown in Eq. 5.5. This equation reveals that higher pressure leads to a lower mass, indicating that games with higher stakes are generally less challenging or stochastic. This finding deepens our understanding of the intricate relationship between pressure, density, and mass in games and how they shape the gaming experience.

$$m = 1 - \sqrt{\frac{P}{2\rho}} \tag{5.5}$$

Sports fans often fantasize about underdog stories, where a lesser skilled team triumphs over a stronger team [77]. These stories are usually more memorable and exciting to viewers as the outcome is highly unpredictable. The appeal of an underdog story also comes from the bond felt between viewers and the underdog team, driven by empathy and a gravitational bond between them [78]. However, the appeal from the player's point of view needs to be clearly known. Some speculated that underdog teams have lesser expectations than the stronger team, leading to less stress felt by the players towards the game's outcome. A stronger team is often expected to win the game, making the stakes higher for them in return.

Let's take an example of a game of soccer between Team A and Team B. Team A has a 70% odds of winning, while Team B only has 30%. Using Eq. 5.3, we can assume that Team A would feel a higher pressure compared to Team B as pressure is directly proportional to velocity (which is equivalent to the winning rate). Hence, the stakes for Team A are much higher than those of the underdog team, Team B, making it much more stressful for players in Team A. On the other hand, the Underdog team can play more casually and more relaxedly. This difference in stakes could be why underdog teams manage to win even when they are less likely to win, as the stronger team is under more pressure and stress, leading to possible choking throughout the game.

Most people generally perform poorly under pressure, but there are some individuals who thrive in high-stress environments. For the majority, stress can impair cognitive function, decision-making, and overall performance, leading to sub-optimal outcomes. However, a subset of people find that pressure enhances their focus, motivation, and efficiency, enabling them to excel when the stakes are high. This ability to perform well under stress can be attributed to a combination of personality traits, coping mechanisms, and experience in managing high-pressure situations. Our findings suggest that MOBA players belong in the latter group as high-pressure environment is often preferred.

5.5 Chapter Summary

In summary, we explored the critical distinction between difficulty and pressure in games. Our analysis primarily focused on spatial pressure concerning the number of players involved. Our previous understanding of the motion in mind theory illustrates how mass influences the difficulty of a game: the slower the game's progress rate, the higher the degree of challenge. However, pressure relates more to the options available to players, determined by the degree of freedom within the game.

For instance, a larger field provides players with more freedom and options, reducing the risk when attempting goals. In contrast, when players have limited options, they must take higher risks to achieve their goals, introducing a different form of difficulty compared to mass. Additionally, we can generalize that having more players in a game increases its unpredictability, making it less deterministic.

Most individuals perform worse under pressure, though some thrive in such conditions. To maximize player satisfaction and engagement, games should strike a balance between difficulty and pressure, leveraging the motion in mind theory. By utilizing our proposed method to evaluate pressure, developers can create experiences that cater to a wide range of player preferences and maintain an optimal level of challenge.

Chapter 6

Monitoring Player Emotions and its Relationship with Motion in Mind

6.1 Chapter Introduction

This chapter outlines the results of experiments done for two games: Genshin Impact and Overcooked 2. For each game, the participant was strapped to a heart rate monitor while playing the respective games to determine possible emotional changes throughout the session. Surveys were also conducted to obtain further feedback from the participants to better understand how they felt during the game session. Results are then analyzed and compared with previously obtained results from prior works.

6.2 Experiment A: Random reward games

The first experiment studies how random reward games impact players emotionally. The gacha from Genshin Impact is used as the test bed for collecting data for this experiment. The first subsection below details a brief background on the game, followed by the procedures of the experiment. Finally, the results gathered from the experiment will be analysed to better understand players' emotions during gacha.

6.2.1 Background of gacha in Genshin Impact

Genshin Impact is an open-world action role-playing game (RPG) developed by HoYoverse. Set in the expansive and visually captivating world of Teyvat, the game offers a blend of exploration, combat, and intricate storytelling. Players engage in various activities such as solving puzzles, battling enemies, and completing quests to uncover the game's rich lore. A key feature of Genshin Impact is its character acquisition system, which operates through a gacha mechanism. This system uses in-game currency, earned through gameplay or purchased with real money, to make randomized "Wishes" that can yield anything from common items to rare, powerful characters and weapons. This element of chance not only adds excitement but also drives player engagement and spending.

The gacha system in Genshin Impact is designed with various banners offering different characters and items for a limited time, each with specified rates for obtaining different rewards. To mitigate player frustration associated with randomness, the game includes a pity system that guarantees a high-tier reward after a certain number of unsuccessful pulls. This approach keeps the game engaging by regularly introducing new content and leveraging the psychological appeal of randomness and scarcity. Overall, Genshin Impact successfully combines an open-world RPG with a gacha-based acquisition system, creating a dynamic experience that maintains player interest through exploration, combat, and the allure of obtaining new characters and items.

In most gacha games, a short animation will play before displaying the results of the items obtained, hinting at the results of the items they obtained. In Genshin Impact, this is depicted with an animation of shooting stars with different colors. When it is purple, it means that gacha only contains a 4-star, but when it is gold, that signifies that gacha contains a 5-star. Figure 6-1 shows how the animation looks when the player obtains a 4-star or a 5-star, respectively. Oftentimes, players get excited when they see this gold shooting star animation as it confirms that they received at least one 5-star item. A previous study on techno-stress highlighted how gacha causes players to feel distressed and eustress, notably annoyance, frustration, disappointment, excitement, and satisfaction due to the uncertainty and randomness [79].

Figure 6-1: Screenshot of Gacha animation for 4-star and 5-star characters (2023), Image courtesy of Hoyoverse

6.2.2 Experimental Procedures

This experiment examines how the player's emotions change while playing a gacha game. A heart-rate monitor will be attached to the respondents throughout the experiment to monitor the changes to the heart rate based on their actions in the gacha. We hypothesized that an increase in heart rate results from excitement, while a decrease is due to disappointment. The time intervals between subsequent gacha were also measured to check the impulsiveness of the respondents. A player who is highly addicted would not spend less time thinking about how they are spending their money.

We used Genshin Impact Wish Simulator, which is available for free, to simulate the gacha for this experiment [80]. Before they started playing the gacha, we asked the respondents to choose two characters, one that they liked the most and another that they disliked. Then, they will start playing the gacha and see if they can obtain their chosen characters. During the experiment, they must navigate to the top-up screen to purchase the currency used for the gacha. Since we are using a simulator, actual money was not spent. However, the price of the purchased gems is shown, which serves as a reminder to the respondents of how much they spend on the gacha. After the experiment, the respondents will answer a small questionnaire asking how they felt about the gacha and if they remember how much they spent in the experiment.

We aim to obtain at least ten respondents for the experiment.

Figure 6-2 shows a screen capture of the recording from the experiment. We used TeamViewer to mirror the screen from a Microsoft Surface Tablet and Smartphone to another desktop, recording both screens simultaneously. The Heart Rate Record application shows the heart rate in beats per minute (bpm) and visualizes it as a line graph. In general, the heart rate of the respondents is not over 110 bpm as they are not doing any physically straining activities. The blood pressure before and after the experiment is also recorded for reference. Blood pressure did not differ much and will be omitted in this study.

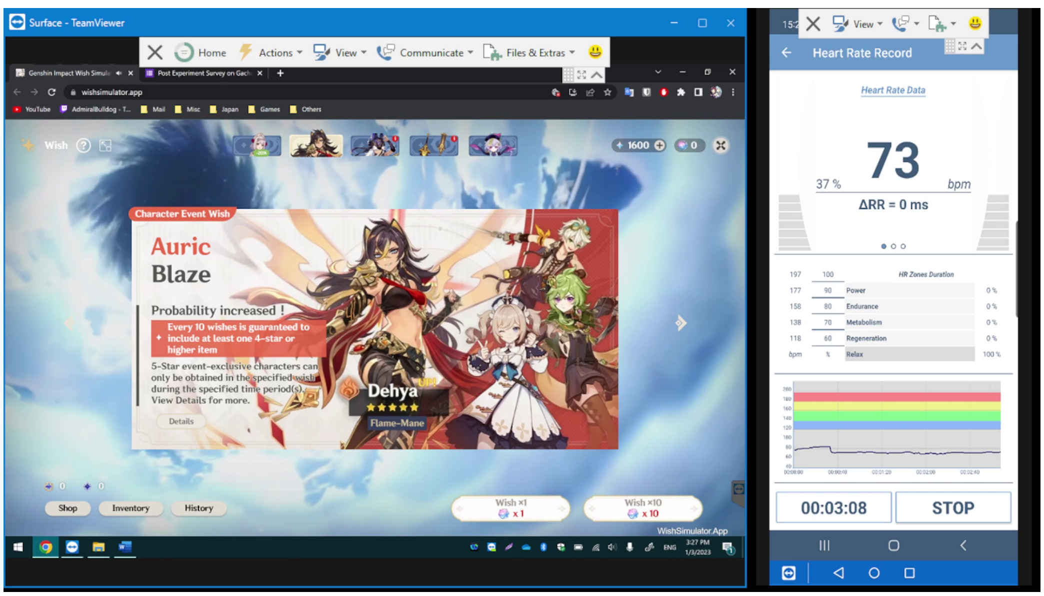

Figure 6-2: Screenshot of experimental set up

In addition to the experiment, we also conducted an online questionnaire prior to the experiment. The questionnaire was carried out using Google Forms, and responses were collected online via the Reddit website, an online discussion forum organized into communities based on interests, topics, and media. The link to the questionnaire was posted on the official Genshin Impact Reddit, and 202 responses were collected. After filtering out the invalid responses, 190 valid responses were identified.

The questionnaire has three main sections, with 29 questions covering demographics, consent, and Gacha games (specifically, the Genshin Impact game). If the user has played Genshin Impact, they will proceed to the second section, which focuses on

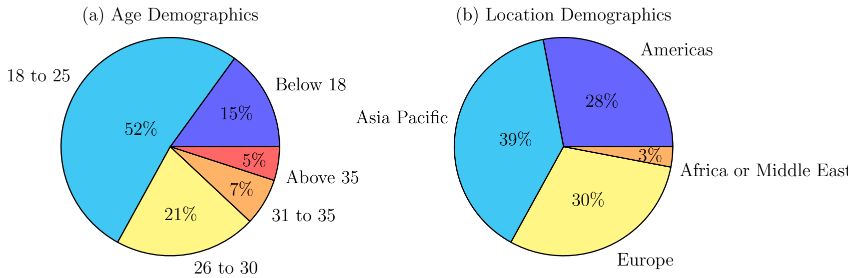

Figure 6-3: Demographic data on age and location

gacha for Genshin Impact. Otherwise, they will be directed to the third section for similar questions about gacha games in general. The second and third sections ask about spending habits, motivation, impulsivity, perceived luck, and the importance of chance on a scale of 1 to 5.

An online questionnaire is a valuable tool for understanding gacha game enthusiasts. It helps to obtain insights and data that would be difficult to obtain otherwise, such as motivations for playing, preferences, and overall satisfaction. Collecting diverse opinions can draw meaningful conclusions and make informed decisions within the industry.

6.2.3 Results and analysis

The results are organized into two distinct sections to analyze the data obtained from the online questionnaire and the experiment.

Online Questionnaire

Figure 6-3 shows the age and location demographics of the respondents. Most Genshin Impact players are young adults between 18 and 30 years old; only 12% were above 30. Regional popularity is highest in Asia Pacific (Central & South Asia, Northeastern Asia, Southeastern Asia, Australia, and Oceania), which is to be expected due to the anime-inspired aesthetics of the game.

Figure 6-4 shows the spending habits of the respondents in Genshin Impact. Spending habits in Genshin Impact can be divided into several categories:

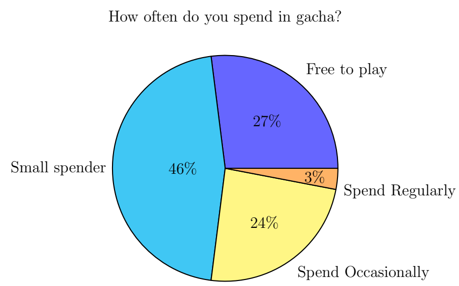

Figure 6-4: Player Spending Habits

- Free-to-play: Player who doesn't make any purchases and only uses the gems earned by playing the game to play the Gacha.
- Small spender: Players who only buy the daily pass or battle pass. The player only spends less than US$10 a month.
- Spend occasionally: Player who also purchases the gem bundles from time to time to play the Gacha. Players often spend more than US$10 a month.
- Spend regularly: Player who purchases the gem bundles always and tries to obtain multiple copies of characters or weapons from the Gacha, often spending more than US$100 a month.

Genshin Impact has multiple gacha that feature different characters, which prompts the question of why players choose to play the gacha for that specific character. Figure 6-5 shows the reasons or motivation for the player when choosing to play a particular gacha in the game. Most respondents only play the gacha when they want to obtain the item featured in the gacha, while only 6% of them play the gacha to simply try their luck. Results from questions regarding player impulsiveness, luck, regret or disappointment, social influence, and overspending have been summarized in Table 6.1.

Finally, the respondents were asked to rate the importance of chance in making gacha games fun on a scale of 1 to 5, where scoring one signifies that chance is not essential and scoring five signifies that chance is very important. The majority of the respondents scored 3 and 4, with the mean score obtained being 3.2.

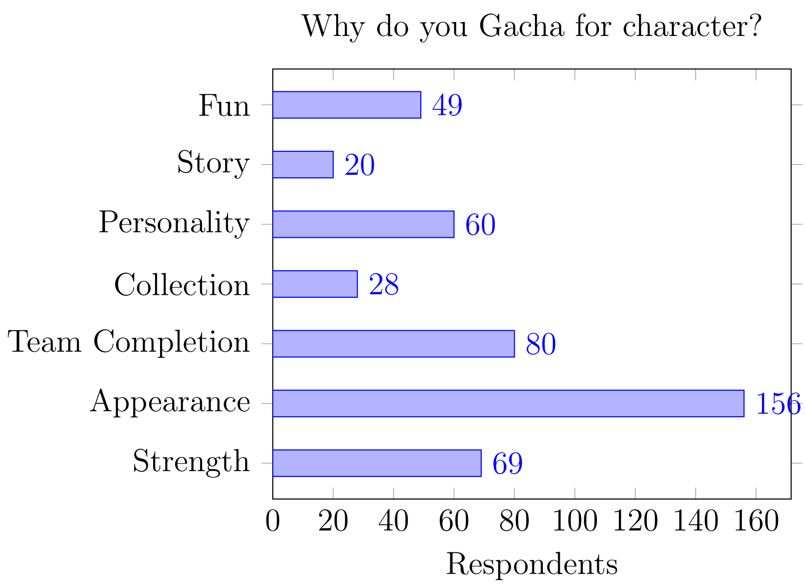

Figure 6-5: Player Motivation to Gacha

Table 6.1: Summarized results from Questionnaire

Question	Results from Respondents		
	% of Yes	% of No	% of Maybe
Have you impulsively played a gacha before?	58	38	4
Do you think you are lucky?	23	39	38
Have you ever felt regret or disappointment from the gacha?	51	36	13
Do you feel regret or disappointment when you have to spend money to gacha?	35	65	-
Do you think social aspect of gacha influences your spending habits?	16	70	14
Have you ever spend more than what you planned for in a gacha game?	34	66	-

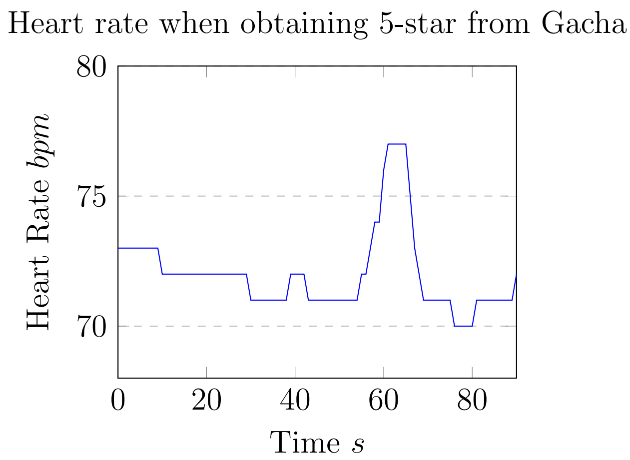

Figure 6-6: Example heart rate recorded from experiment of respondent with idle heart rate of 72 bpm

Experimental results

A total of 15 responses were collected, but after filtering out invalid results and responses, we have 13 responses. All respondents were students from Japan Advanced Institute of Science and Technology (JAIST) above the age of 25. Seven of them have prior experience with playing gacha games, while the remaining six have not played gacha game before this.

Each respondent's average resting (idle) heart rate was recorded before the start of the experiment. The focus was on the sudden changes in heart rate due to gacha results. Figure 6-6 shows a case where the respondent shows an increase in heart rate when a 5-star item was received.

In the experiment, we observed that out of 13 respondents, ten respondents had an observable increase in their heart rate when they saw the gold shooting star animation. On the other hand, one of the respondents had a decrease in their heart rate, while the remaining two had no apparent changes in their heart rate when they obtained a 5-star character. The majority of the respondents feel excited as an increase in their heart rate signifies that they are anticipating something from the gacha. A decrease in heart rate shows their disappointment with the results from the gacha. Recall that the respondents first chose the character that they liked before starting. All three respondents who did not show an increase in their heart rates did not obtain the character that they chose at the start. Hence, the decrease in their heart rate may be due to their disappointment as they did not receive the character they wanted.

Figure 6-7 presents a scatter plot depicting the changes in heart rate observed during the experiment against the number of attempts required to obtain a 5-star item. Using linear regression, we can model the heart rate change using the formula 2.29+0.03(Number of attempts). It is evident that players who needed more attempts or unlucky exhibited a higher increase in heart rate. This indicates that players experience higher stress after more attempts, resulting in a greater increase in heart rate compared to their idle state.

Motion in mind predicted that players would feel most engaged between 30 and 40 attempts. However, our experiment does not include many instances in this range, with those that do show only minor changes. Interestingly, being lucky in gacha (obtaining the desired item quickly) does not appear to significantly influence heart rate.

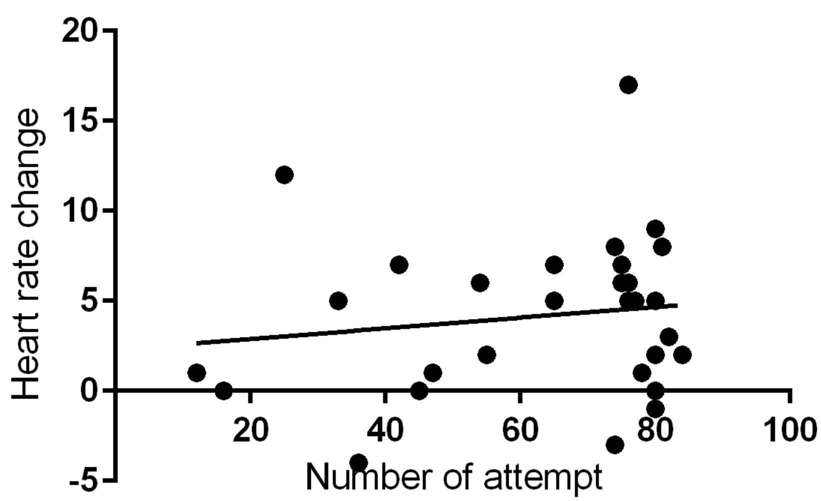

Figure 6-7: Scatter plot of the increment of heart rate with respect to the number of attempts to obtain the 5-star item

After the experiment, the respondents were given a small questionnaire to record their feedback from the gacha session. Results regarding the spending amount and perceived luck from the survey are summarized in Table 6.2.

Table 6.2: Summarized results from Post-Experiment Survey

Question	Results from Respondents		
	% of Yes	% of No	% of Maybe
Do you remember how much you spent?	54	46	-
Would you spend if it was real money?	31	69	-
Do you think you are lucky?	8	38	54
Have you played gacha games previously?	54	46	-

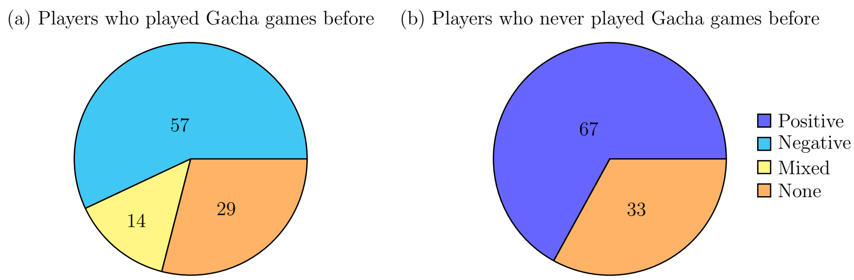

Figure 6-8: Emotions felt by players during the Experiment

Respondents were also asked how they felt in an open-ended question, which was divided into positive and negative, as shown in Table 6.3. We also found that players with prior experience with gacha took shorter time intervals between subsequent gacha, where they took an average of 20 seconds, while players new to gacha games took 30 seconds between each attempt. Figure 6-8 shows the emotions felt by players during the experiment.

Table 6.3: Examples of positive and negative emotions

Positive Emotions	**Negative Emotions**
Excited, Curious, Ambitious, Desired, Happy	Bored, Hesitant, Disappointed, Annoyed

Similar to the online questionnaire, the experiment's respondents were also asked to rate the importance of chance in making gacha games fun on a scale of 1 to 5, where scoring 1 signifies that chance is not important and scoring 5 signifies that chance is very important. The majority of the respondents scored 4 and 5, with the mean score obtained being 4.1.

6.2.4 Discussion

Most Gacha game players feel unlucky, with only 23% believing in their luck. The loss aversion bias explains this situation, where losses are perceived as more impactful than wins. Over half of the participants experienced regret and disappointment. Familiarity with Gacha games caused no positive emotions, while those who had never played had no negative emotions. Impulsive behavior was observed among 58% of the respondents who had previously played Gacha games. Overspending on microtransactions in Genshin Impact's Gacha game was found to be a significant risk, with over a third of the respondents admitting to it. Previous research has linked gambling disorder to microtransactions, indicating that adolescents who purchase loot boxes may be at greater risk of developing gambling disorders [81]. The questionnaire revealed that players are more likely to spend real money than using the free currency earned by playing the game. A mere 27% of players play the game without spending any money.

Players are not necessarily addicted to Gacha games because of completionism (28 respondents were identified as playing Gacha to collect certain characters), but collecting characters can contribute to compulsive behaviors. Genshin Impact emphasizes unique character design and introduces new characters through events and quests, making them even more appealing to players. Most players are drawn to the game because of their character appearance, personality, and strength. Gacha games' discounting theory and FoMO make them more attractive since most characters are time-limited, forcing players to spend all their in-game currency to obtain them before the timer runs out.

Our experiment's findings also show that a heart rate monitor can record a player's anticipation. The gacha done in this experiment was through an online simulator, where respondents did not lose anything from failing as it was completely free. Hence, there were no stakes in the outcome for the player. We feel that this diminishes the connection felt by the player towards the gacha, reducing the possible excitement or disappointment due to the outcome. In the future, we wish to design an experiment that maximizes the stakes for the respondents to ensure a more realistic outcome.

6.2.5 Limitations

One significant limitation of the experiment is that the respondents did not spend any money while engaging with the gacha mechanics. Since an online simulator was used to collect data, participants did not experience the sense of loss or gain typically associated with spending real money on gacha games. This lack of financial investment likely resulted in a reduced emotional engagement compared to regular gacha players, who are more invested in the outcomes.

Furthermore, nearly half of the respondents had no prior experience with gacha games. Their unfamiliarity means they lack a reference point for determining whether they were truly lucky or not, which could diminish their excitement or disappointment. We believe this affected the heart rate readings, as real gacha players who spend actual money might exhibit more pronounced physiological responses.

Additionally, we suspect that casual gacha players and "whales" (those who spend substantial amounts on gacha) would show different results. Whales, due to their significant financial investments, might exhibit higher emotional stakes and consequently more significant physiological spikes in response to their gacha pulls.

6.3 Experiment B: Cooperation focused game

The second experiment that was conducted studies how cooperation focused games impact players emotionally. The popular couch co-op game Overcooked! 2 will be used to collect data for this experiment. A brief background on the game is detailed in the first subsection below, followed by the procedures of the experiment. Finally, the results gathered from the experiment will be analysed to investigate how number of players affect games in a cooperation focused game.

6.3.1 Background of Overcooked! 2

Overcooked! 2 is a cooperative cooking simulator game released in 2018 and developed by Team17 alongside Ghost Town Games [82]. It was one of the most popular couch co-op games released in the year, with reviews and ratings being very positive [83]. The goal of the game is to team up with up to four players acting as chefs in a kitchen to complete food orders as quickly as possible within the timeframe provided [84]. Figure 6-9 shows the kitchen layout with labels on important game aspects in a level from Overcooked! 2.

Figure 6-9: Screenshot of the kitchen layout in Overcooked! 2. Important game elements are highlighted using labels.

The top left corner of the game shows a food order list and the recipes/ingredients for each dish from the order. From Figure 6-9, the dish requires three ingredients: seaweed, rice, and fish. The rice has an icon of a pot below it; hence, it must be processed (boiled) beforehand using the pots circled below in green. The fish must also be cut using the chopping board on top, circled in green. Cutting, boiling, frying, steaming, and so on are considered as processing the food. The number of ingredients and processing requirements increases the points obtained when sending out the dish through the serving window. Players also receive tips based on how fast the order was completed. The total points currently can be seen in the bottom left corner, while the time remaining for the level is shown in the bottom right corner. Some levels have added difficulties, such as obstacles and fire hazards, which players must be mindful of.

Players earn points based on the correctness of the order and how quickly it was completed. While it may seem beneficial to crank out orders as they're finished, it's usually better to deliver dishes in the order they appear on the food order list (from left to right), as shown in Figure 6-9. Players should remain focused on the leftmost order displayed and put effort into completing that dish first while being mindful and getting things ready for the next one listed [85]. Below are the scoring criteria for Overcooked! 2 as obtained from [86]:

- Submitting a dish will net players 20 points per ingredient processed.
- Submitting the dish early (green timer above the recipe on the food order list) nets players 8 points as tip.
- Submitting the dish when it has a yellow timer nets players with 5 points as tip.
- Submitting the dish when it has a red timer nets players with 3 points as tip.
- After submitting two dishes sequentially, as shown in the food order list above, the tip received on the third dish is doubled.
- After submitting three dishes sequentially, as shown in the food order list above, the tip received on the fourth dish is tripled.
- After submitting four or more dishes sequentially, as shown in the food order list, the tip received for the dish is multiplied by four.
- Failing any order deducts 30 points from the total.

The players received 68 points, as the screenshot was taken in Figure 6-9, evidenced by the "+68" text in the bottom left corner. The submitted order contains three ingredients: seaweed, rice, and fish, which should net 60 points. The player also received a tip of 8 points as this was submitted while it still has a green timer (or 3 HP bars above the recipe). Hence, a total of 68 points were awarded to the players who submitted the order successfully.

The example in Figure 6-9 shows two players (or chefs) circled in red. As mentioned previously, Overcooked! 2 can be played by up to four players. However, when playing alone, there will still be two chefs, not one. The player then has to control both chefs by switching between each to complete separate tasks and finish the level, adding to the game's complexity.

Overcooked! 2 has been utilized by previous works to evaluate team collaborations and analyze teamwork capabilities by studying performance and communication measures made by players in the game [84,87,88]. Powerful planning language PDDL was also used to develop a solver for Overcooked by simplifying the game's rulesets into a planning problem, successfully solving a typical level from the game [89]. Our focus in this article is to analyze the game using motion in mind to discover objective and subjective emotions from the players' perspective.

6.3.2 Experimental Procedures

We conducted the experiment by asking the respondents to play six stages from the first and second world levels (12 games played). The experiment is carried out four times, with the first run involving only one player, the second run involving two players, and the third and fourth runs involving three and four players, respectively. The gameplay is recorded and saved in video form for reference. A heart-rate monitoring armband was also attached to the respondents throughout the experiment, and changes to their heart rate were recorded.

Players played each level sequentially, starting from the tutorial level, followed by levels 1-1 up to levels 2-6, for a total of 13 games. The tutorial level was not considered in this research as it was just an introductory level with no timers and no scores.

All the experiment participants were casual game players; hence, their skill levels were relatively similar. The games were played while the players were in a voice call together, enabling them to discuss and communicate with each other.

6.3.3 Results and analysis

The results obtained from the experiment are tabulated in Table 6.4 below. The key takeaway from the experiment is the number of orders completed, number of orders failed, number of orders remaining, and the points obtained by the player(s), as these will be used to evaluate the velocity v of the game using motion in mind.

Table 6.4: Summary of results obtained from the experiments

Level	One player				Two players				Three players				Four players			
	OC	OF	OR	Score	OC	OF	OR	Score	OC	OF	OR	Score	OC	OF	OR	Score
1-1	19	0	2	636	30	0	2	1032	30	0	2	896	39	0	1	1420
1-2	10	0	4	812	13	0	4	1076	9	0	5	708	14	0	5	1180
1-3	6	0	5	306	9	0	5	440	8	0	5	381	10	0	4	443
1-4	5	0	5	325	7	2	5	406	7	0	5	471	9	2	5	523
1-5	5	0	5	281	9	0	5	483	6	0	5	319	12	0	5	671
1-6	9	0	5	489	11	1	5	496	15	0	5	841	14	0	4	691
2-1	5	0	4	266	7	0	5	348	11	0	4	576	14	0	5	715
2-2	4	0	5	312	5	2	5	331	7	1	5	521	7	3	5	435
2-3	4	0	5	265	5	2	5	272	6	1	5	361	7	2	4	394
2-4	4	4	5	227	9	3	5	710	10	1	5	839	15	2	5	1292
2-5	4	1	5	318	5	2	5	361	6	1	5	475	9	2	4	694
2-6	4	2	5	162	10	2	5	578	17	0	4	1037	17	1	3	993

OC: Orders Completed OF: Orders Failed OR: Orders Remaining

Figure 6-10 below illustrates the number of orders completed per level with respect to the number of players in the game, as tabulated in Table 6.4. It is apparent that having more players increases the number of orders completed at the level. However, three-player settings have some inconsistencies from 1-2 to 1-5, where the number of orders completed is occasionally lower than one or two-player settings. Based on the feedback from the respondents, they felt that the kitchen in these levels needed to be bigger to accommodate three players, leading to congestion and disorder. However, having four players in the same kitchen did not share these inconsistencies. Perhaps players needed to communicate more effectively during the levels and were disorganized, leading to lesser order completions.

Many online forums suggested that Overcooked! 2 can be played with two players but is ideal with three or four players [90, 91]. Some even argue that the two-player

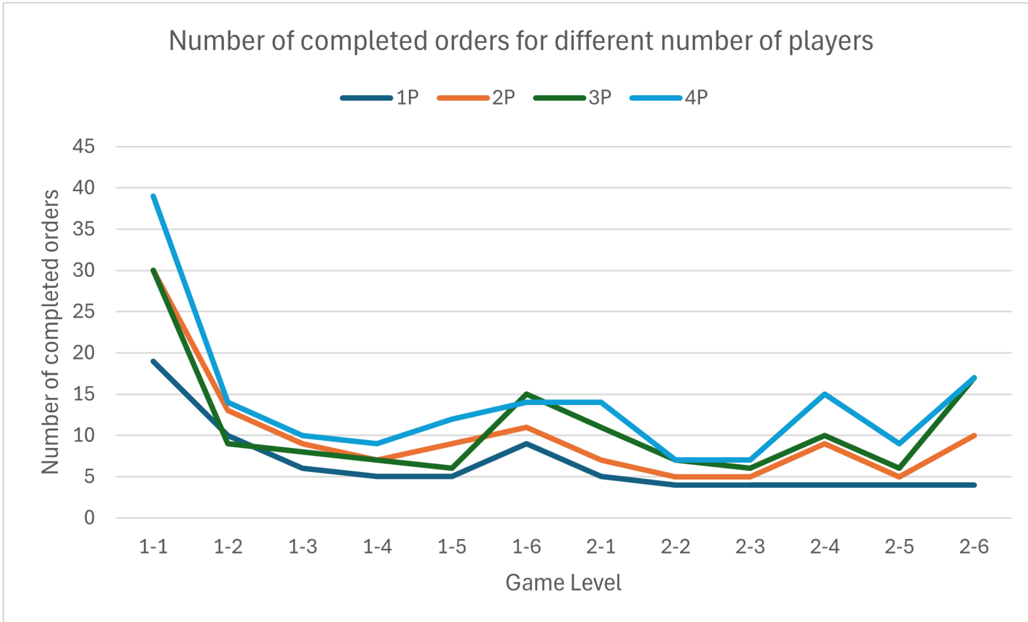

Figure 6-10: Number of completed orders for respective levels throughout the experiment

setting is the most fun way to play the game [92]. We hope to find an objective answer to the ideal settings for this game by utilizing motion in mind.

The velocity of each level in the game can be evaluated using Equation 6.1, derived from Equation 2.1. Initially, we attempted to use the number of completed orders as a metric to assess the velocity. However, the number of orders is technically endless as it depends on the speed at which players complete the order. In most levels, the food order list from Figure 6-9 has a maximum of 5 orders at a time. If players complete an order, a new order will be added in its place, making the number of remaining orders constant.

$$v_1 = \frac{OrdersCompleted}{TotalOrders} \tag{6.1}$$

The game progress can also be determined using the score or points obtained throughout the level. A perfect game (v=1) would be achieved if the players managed to obtain the maximum theoretically obtainable points. The maximum points are calculated using the ruleset explained previously in the experimental procedures based on [86]. As such, we propose another formula for evaluating the velocity, as shown in

Equation 6.2.

$$v_2 = \frac{Score}{TotalObtainableScore} \tag{6.2}$$

The velocity of each level played during the experiment is then evaluated using the formula in Equation 6.1 and Equation 6.2. The results are then tabulated in Table 6.5. The two velocities show two distinct evaluations of game progress: number of orders completed as v_1 and score/points from finishing the level as v_2.

Table 6.5: Velocity for each level with respect to number of players

Level	One player		Two players		Three players		Four players	
	v_1	v_2	v_1	v_2	v_1	v_2	v_1	v_2
1-1	0.90	0.69	0.94	0.69	0.94	0.50	0.98	0.73
1-2	0.71	0.96	0.76	0.96	0.64	0.77	0.74	0.97
1-3	0.55	0.85	0.64	0.74	0.62	0.67	0.71	0.73
1-4	0.50	0.84	0.50	0.56	0.58	0.76	0.56	0.57
1-5	0.50	0.91	0.64	0.84	0.55	0.73	0.71	0.85
1-6	0.64	0.82	0.65	0.62	0.75	0.77	0.78	0.71
2-1	0.56	0.86	0.58	0.77	0.73	0.74	0.74	0.70
2-2	0.44	0.93	0.42	0.53	0.54	0.68	0.47	0.49
2-3	0.44	0.90	0.42	0.50	0.50	0.64	0.54	0.54
2-4	0.31	0.31	0.53	0.58	0.63	0.73	0.68	0.71
2-5	0.40	0.67	0.42	0.53	0.50	0.68	0.60	0.61
2-6	0.36	0.42	0.59	0.62	0.81	0.78	0.81	0.73

Figure 6-11 shows the trend of velocity v_1, which is the game progress with respect to the number of orders submitted. The velocity generally increases when the number of players increases. Two-, three-, and four-player formats share similar trends across the levels, sharing similar dynamics of velocity. As such, we conjecture that players feel similar emotions and have a sense of familiarity due to these identical patterns of velocity. Playing alone, on the other hand, only shares the pattern during levels 1-6 to 2-3 but is significantly different on other levels. This could be why players feel that playing alone is boring and tends to be too difficult or impossible on certain levels [91]. As respondents in this experiment only play stages from the first and second levels, the difficulty is not too high to make it impossible to complete alone.

A stage from much higher levels could show a more significant difference in velocity compared to what we could observe from this article.

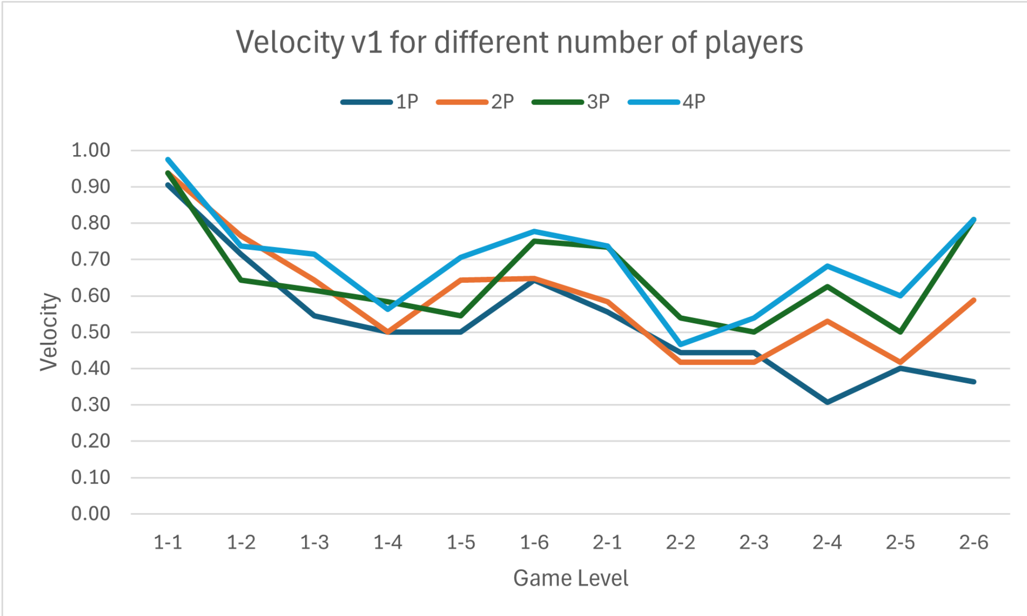

Figure 6-11: Velocity v_1 for respective levels throughout the experiment

Figure 6-12 then illustrates the trend of velocity v_2, which is the game progress with respect to the score of the game. Like in v_1, we can spot similarities in the dynamics of velocity between two and four player settings. Single player setting shows drastic fluctuations of velocity towards the later levels of the game (2-3 to 2-6) due to an imbalance of difficulty. There is a sudden spike in difficulty at 2-4, where the player failed to deliver four orders, leading to a much lower score than expected. The three-player setting on the other hand had a significantly different dynamic to its velocity when concerning the score obtained in the game. We believe that this happened due to the lack of communication, as explained previously.

This sudden change in velocity leads to discomfort in players' minds, similar to the sensations of jerking on roller coasters. A high jerk signifies a sudden change in acceleration and velocity. Zhang et al. [66] studied popular roller coasters worldwide and discovered that the comfort or discomfort felt by riders stemmed from jerk in mind. As such, sudden and disruptive changes in velocity create discomfort among players, making it feel less enjoyable to them.

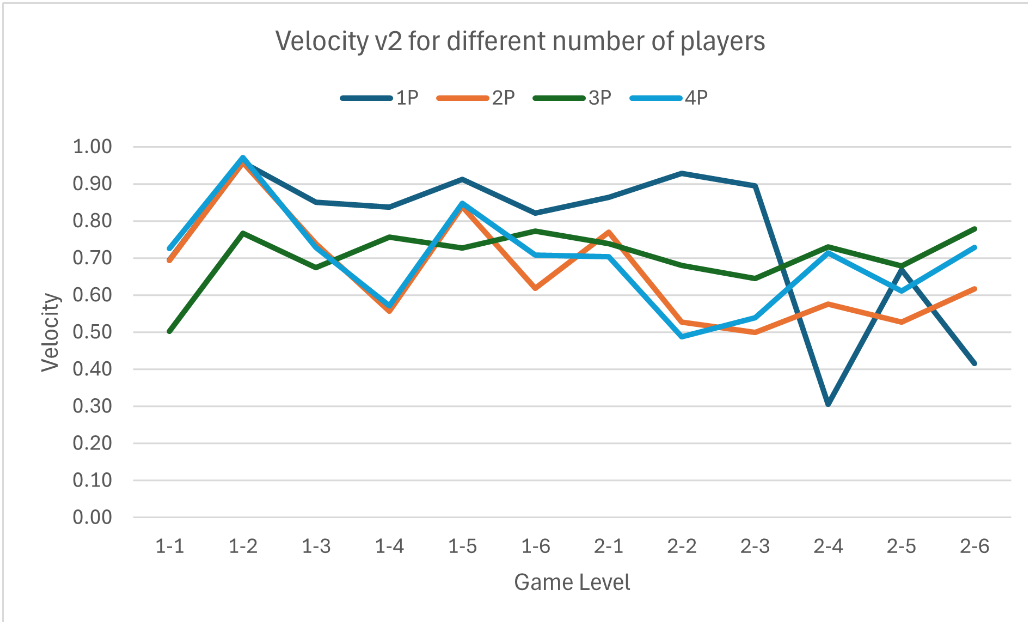

Figure 6-12: Velocity v_2 for respective levels throughout the experiment

We hypothesize that two and four-player settings are ideal for the Overcooked! 2 levels studied in this experiment. Both of these settings have similar dynamics consisting of ups and downs like a roller coaster. The fluctuations are not too drastic, leading to excitement and comfort in the minds of players.

Both single and three-player settings, on the other hand, are not recommended as they would not provide the best experience and comfort for players. Single player setting showed a drastic drop in velocity towards the later stages as the levels become too challenging for the player to tackle alone. This drastic drop makes player feel discomfort in mind due to the sudden change of difficulty. Three-player settings however shows that the velocity are somewhat constant with little to no fluctuations. A roller coaster without any ups and downs would be boring as there is not enough jerk to incite some excitement among players. Hence, our results for three-player setting would suggest that this mode would feel boring to players.

We first need to obtain the density to evaluate the pressure in players' minds during the experiment. In Overcooked! 2, even when playing alone, there will always be two chefs in the kitchen, and the solo player has to control both chefs to complete the level. Hence, the game's chefs range from two to four people. The size of the kitchen at each level is always the same despite the number of players in the game. Let the size of the kitchen be a constant of $K = 1$, then the density in game with four player is $4/K = 4$. Similarly, the density of three, two, and one player would be 3, 2, and 2 (not 1, as there still are two chefs). The average velocity of v_1 and v_2 is used instead for the calculation of pressure.

Table 6.6: Average velocity, density, and pressure for each level with respect to number of players

Level	One player			Two player			Three player			Four player		
	Velocity	Density	Pressure	Velocity	Density	Pressure	Velocity	Density	Pressure	Velocity	Density	Pressure
1-1	0.80	2	2.56	0.82	2	2.66	0.72	3	3.11	0.85	4	5.79
1-2	0.84	2	2.80	0.86	2	2.97	0.70	3	2.98	0.85	4	5.83
1-3	0.70	2	1.95	0.69	2	1.91	0.64	3	2.50	0.72	4	4.16
1-4	0.67	2	1.79	0.53	2	1.12	0.67	3	2.69	0.57	4	2.57
1-5	0.71	2	1.99	0.74	2	2.19	0.64	3	2.43	0.78	4	4.82
1-6	0.73	2	2.14	0.63	2	1.60	0.76	3	3.48	0.74	4	4.42
2-1	0.71	2	2.01	0.68	2	1.83	0.74	3	3.25	0.72	4	4.15
2-2	0.69	2	1.89	0.47	2	0.89	0.61	3	2.22	0.48	4	1.82
2-3	0.67	2	1.79	0.46	2	0.84	0.57	3	1.96	0.54	4	2.32
2-4	0.31	2	0.38	0.55	2	1.22	0.68	3	2.75	0.70	4	3.90
2-5	0.53	2	1.14	0.47	2	0.89	0.59	3	2.08	0.61	4	2.93
2-6	0.39	2	0.61	0.60	2	1.45	0.79	3	3.78	0.77	4	4.74

Having more players results in higher pressure as the player density is directly proportional to the pressure felt in mind. We conjectured that pressure in the game context depicts the level of stakes or risk-taking tendencies. A high-pressure game might not necessarily be challenging, but players might take considerable risks to achieve goals.

For example, in a game with four players in Overcooked! 2, players can divide the tasks among each other to maximize their efficiency. Some levels require players to cut, boil, steam, or fry the ingredients, as well as wash the dirty dishes. Having more players allows division of labor, and players can focus on only one task at a time. Playing alone would be tougher, as the player needs to multitask in order to complete the level successfully.

Looking back at Equation 5.3, the density of players ρ is inversely proportional to the velocity v. On the contrary, the velocity observed in Table 6.6 is generally higher when there are more players. Our previous conjectures for pressure only considered competitive games but not fully cooperative games. Overcooked! 2 is an entirely cooperative game where all players work together to achieve points. Hence, the game becomes more deterministic, observable by the velocity approaching 1. In a competitive game such as soccer, having more players on each side would increase the stochasticity of the game, making the outcome more unpredictable. Our findings in this paper suggest a crucial distinction between cooperation and competition games with respect to pressure in mind.

Table 6.7: Average, minimum and maximum heartrate in beats per minute *bpm*

Players	Average BPM	Min BPM	Max BPM
One	77	59	93
Two	76	64	108
Three	72	60	93
Four	69	54	99

Table 6.7 records the players' average, minimum, and maximum heart rate data throughout the experiment. It could be observed that the average heart rate decreases when there are more players in the game. As observed previously in Table 6.5, the velocity generally increases when there are more players in the game, depicting an inverse relationship between velocity and the heart rate of players when playing the game. Higher velocity implies that the game is less challenging, leading to less mental stress felt by players.

Another pattern that we observed during the experiment is illustrated in Figure 6-13. The player's heart rate often shows a slight increase as the timer runs out at each level. During the last 25 seconds, players usually felt rushed due to the music in the game becoming more upbeat. Players then worked harder during this time to finish up any order that they could to finish up the level. The example in Figure 6-13 shows the trend in the last 25 seconds of the game, followed by the next 10 seconds after completing the level. The heart rate then gradually decreases after the level is complete, returning back to the idle heart rate.

We believe that time stress causes players to experience tension, leading to an increased heart rate. Players feel a rush of adrenaline during the final 15 to 20 seconds of the level, causing a sense of urgency and heightened pressure. However, when the remaining time drops below 5 seconds, players begin to relax, recognizing

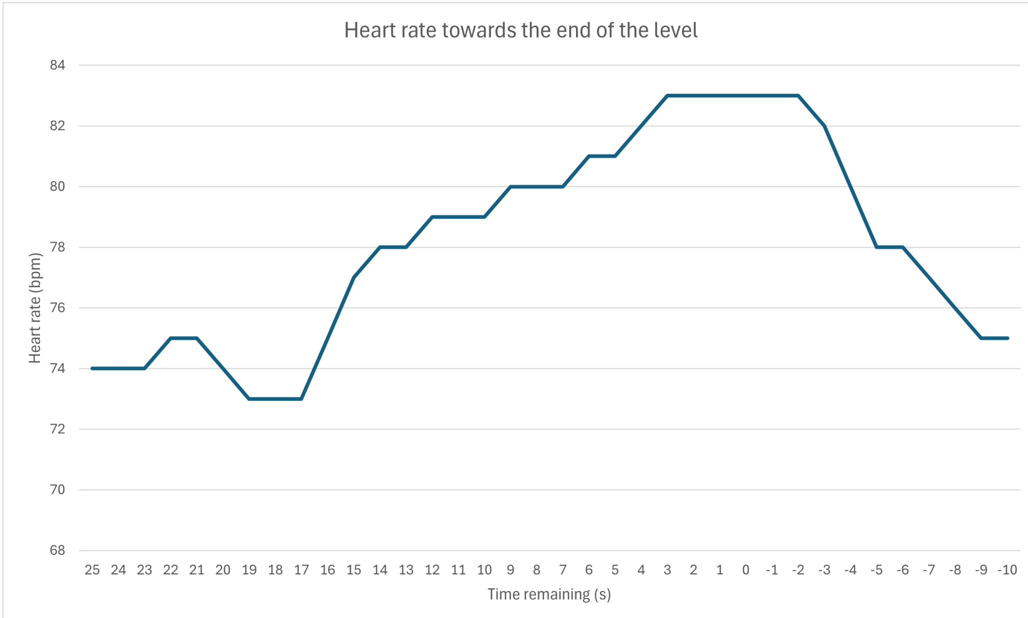

Figure 6-13: Heart rate of players during the end of the game with an idle heart rate of 71 bpm

that there isn't enough time to complete any more tasks. This shift in perception explains why the heart rate starts to decrease immediately after the level ends, as players have already begun to relax a few seconds before the level concludes.

6.4 Chapter Summary

This chapter delved into the emotional impact of gacha and cooperative games, specifically examining Genshin Impact and Overcooked! 2. Through a series of experiments, we identified a slight correlation between heart rate and the concept of motion in mind.

In the case of Genshin Impact, our findings revealed that respondents' heart rates increased whenever they obtained a rare item from the gacha system, likely due to the excitement and anticipation associated with these rewards. This response highlights the emotional engagement players experience during these moments of high reward.

In Overcooked! 2, we observed a different dynamic. The heart rates of players tended to decrease as the number of teammates increased. This phenomenon can be attributed to the distribution of tasks and shared responsibilities, which likely reduces individual stress levels. Additionally, our analysis of velocity indicated that the game becomes more deterministic with more players, meaning that the gameplay outcomes are more predictable and structured compared to the competitive games studied in Chapter 4.

These insights from our study underscore the varying emotional and physiological responses elicited by different game mechanics. Gacha games like Genshin Impact trigger excitement through randomized rewards, while cooperative games like Overcooked! 2 promote a calmer, more predictable gaming experience as team size increases. Understanding these differences can inform the design of games to better cater to diverse player preferences and optimize their emotional engagement.

Chapter 7

Conclusion

7.1 Addressing the Research Questions

After meticulous research throughout this dissertation, the research questions posed in the introduction could now be addressed. Five questions were proposed, which will be described further in the subsections below.

7.1.1 Boundary between game and gambling

The boundary between gaming and gambling was predicted using motion in mind theory. The difference between games of skill and chance is apparent when comparing the reward frequency N, where chance-based games often have much higher N than skill-based games. As N is just the inverse of the probability of winning, the N for lotteries and other forms of gambling could be infinitely larger as the odds of winning are infinitesimally small, reaching one in a billion.

We found that games with $N \geq 55$ can be categorized as gambling as the zero-sum assumption does not hold for gambling games based on Conjecture 3. In other words, when a game has the odds of winning lesser than 2% ($v = 0.018$), it becomes too stochastic and reduces the influence of the player's skills towards the outcome of the game. This sensation feels similar to sensations felt when gambling, making games feel subjectively similar to gambling.

We conjecture that the boundary between game and gambling can be evaluated using $\sqrt[3]{\frac{2}{a}}$, where $N = 55$ or $v = 0.018$ when evaluating it for games located in the GR zone of $[0.07, 0.08]$.

We believe that understanding this boundary can be instrumental in designing optimal experiences for gacha players, significantly enhancing their engagement. By carefully calibrating the balance between reward frequency and emotional impact, game developers can create a more satisfying and compelling experience for players.

For instance, identifying the precise threshold at which the excitement of receiving rare items peaks can help in structuring reward systems that maximize player satisfaction. This involves fine-tuning the drop rates of rare items to ensure they are perceived as valuable and worth pursuing, without making them so rare that players become frustrated or disengaged. Moreover, integrating elements that amplify the emotional highs of receiving rewards can further enhance engagement. This could include visually striking animations, celebratory sounds, or even social sharing features that allow players to broadcast their achievements to friends and the gaming community.

Additionally, understanding player behavior and preferences through this boundary allows for the development of personalized gacha experiences. By analyzing player data, developers can adjust the difficulty and frequency of rewards to match individual play styles, ensuring that both casual players and hardcore enthusiasts find the game equally rewarding.

In summary, leveraging this boundary in gacha game design not only enhances player engagement but also contributes to a more balanced and enjoyable gaming experience. By meticulously crafting the reward system and integrating emotionally resonant elements, developers can foster long-term player loyalty and satisfaction.

7.1.2 Significance of pity system and designing an ideal gacha

The pity system was initially introduced as a safety net for gacha players by creating an artificial ceiling price for items in the gacha. The random nature of gacha makes obtaining a specific item entirely up to luck and could lead to players attempting hundreds or thousands of times before receiving the item they wanted. Hence, introducing the pity system helps set a limit to the number of attempts required, in turn slightly reducing the unpredictable nature of it.

The pity in Genshin Impact is set at 90, meaning that players will always obtain a 5-star character on the ninetieth attempt if they did not receive one after eighty-nine tries. Data collected showed an average of 61.5 attempts to get a 5-star character from the gacha, with the luckiest and unluckiest attempts taking 5 and 83 tries, respectively. Despite over 4600 attempts, there was never an instance where it took exactly 90 attempts to obtain a 5-star character. This anomaly suggests that a hidden algorithm might be influencing the results of each attempt in Genshin Impact.

To understand the broader trends, we compared several popular gacha games, examining the relationship between the pity counter, probability, and price per attempt. Through linear regression analysis, we proposed a formula for evaluating the pity system. Our findings, outlined in Conjecture 4, indicate that the probability of obtaining the desired item has a more significant impact on the pity counter than the price per attempt when the pity counter is lower.

Our analysis suggested that the pity counter for a gacha game with increasing probability can be evaluated using $95.7 - 3.7(\text{Probability})$. Then, the pity counter should generally be lower than 96 as the probability cannot be less than zero, leading to a pity counter that is similar to that in Genshin Impact.

On the other hand, gacha games that utilize a spark system tend to have higher pity counters and are more influenced by the price per attempt rather than the probability of obtaining rare items. This is because the probability of obtaining rare items is typically higher in these games. Our analysis suggested that the pity counter is evaluated using $356.9 - 57.6(\text{Price per attempt})$, indicating that the pity counter should ideally be below 357 to prevent excessive frustration among players.

The motion in mind analysis suggested that players would feel most engaged when they obtain rare items around 30 to 40 attempts as the AD measure would be optimal during this range. This finding, however, contradicts the analysis of various existing games in the market. We believe this contradiction arises because the primary focus of most gacha games is longevity. Setting the pity counter too low diminishes the perceived value of rare items. Scarcity not only provides a stronger emotional attachment to the rare items but also ensures that players continue to support the game over a longer period.

This balance between engagement and scarcity is crucial. While obtaining rare items quickly can boost immediate player satisfaction, it can also lead to a quicker sense of completion and potential disengagement. By maintaining a higher pity counter, developers can create a sense of prolonged achievement and excitement, encouraging players to remain invested in the game. This approach also aligns with the economic model of gacha games, where sustained player engagement translates to continued revenue through in-game purchases. Therefore, while the ideal range for engagement might be 30 to 40 attempts, the higher pity counters found in many gacha games are strategically designed to balance player satisfaction with the need for long-term game sustainability and profitability.

In summary, the ideal pity counter in a gacha game is highly dependent on the probability of obtaining rare items. The pity system serves as a safety net for players, ensuring that they eventually receive the desired item after a certain number of attempts. The price per attempt is crucial for developers, as it constitutes the primary revenue stream for gacha games. Balancing these factors is key to maintaining player satisfaction and ensuring the financial success of the game.

7.1.3 Influence of number of players in a teamwork setting

Previous works have addressed how adding players to a game makes it more stochastic in nature. However, this might not apply when increasing the number of players in a team setting. This dissertation studied multiple team-based sports and their variations. A new formula for calculating the density of players in a game was proposed, where the number of players is divided by the total playing area. The density was then used to evaluate the pressure in games.

As the size of the playing field is used for evaluating the density of players in games, it is difficult to compare between different games as the rules are too different when focusing only on the field size. Hence, spin-offs or alternative versions of the games will be used to make fair comparisons. For example, it is not possible to make a general comparison between soccer and badminton. Still, we could compare soccer and futsal as the rules and play styles are slightly similar.

When comparing soccer and futsal, the smaller version of the game has a higher density and pressure. A higher number of players would generally mean it has a higher density. However, the huge difference in the field size caused futsal to have a higher density than soccer. A similar trend can be seen in basketball as well when comparing it to 3x3, albeit a much smaller difference than that in soccer.

Comparisons between singles and doubles in badminton showed how the game can be categorized by its velocity and reward frequency. Single variants of badminton have similar velocities at $v \approx 0.60$ while double variants have slightly lower velocities at $v \approx 0.58$. Similar velocity causes the men's, women's, and mixed variants to feel familiar to players and viewers. Single variants also showed that they were more deterministic than doubles as they have a greater velocity.

MOBA games are slightly complicated and more complex to generalize. In order to evaluate the density in MOBA games, the number of lanes was used instead of the entire map size, as lanes are essential in a MOBA game. The results in Table 5.4 standard modes in Dota 2 and LoL have higher density and pressure than its spin-off modes. On the other hand, the standard mode in Smite has the lowest density and pressure compared to the other spin-off modes. High pressure might be favorable to players who play MOBA games as both Arena and Joust in Smite are equally, if not more, popular than the standard mode.

Most competitive games analyzed show that games become more stochastic when more players are in the game. A fully cooperative game, on the other hand, shows that games become more deterministic as the number of players increases, evidenced by their increasing velocity in Overcooked! 2. However, pressure shows a similar trend between both types of games, with increasing the number of players leading to higher pressure.

In summary, we believe that increasing the number of players plays a crucial role in achieving a balance between difficulty and entertainment in games. The addition of more players adds layers of complexity and unpredictability, making the game more challenging and engaging. This is illustrated by the concept of increasing mass mm in the motion in mind theory, which correlates to the escalating difficulty and the dynamic nature of the gameplay.

As the number of players rises, the game environment becomes more vibrant and less deterministic, leading to varied and spontaneous interactions. This unpredictability enhances the excitement and replayability of the game, keeping players intrigued and motivated. For competitive games, the higher player count introduces more variables and strategies, making each match unique and testing the players' adaptability and skill.

Moreover, the increased difficulty associated with more players does not necessarily detract from the enjoyment; rather, it often contributes to a more satisfying gaming experience. Players tend to find fulfillment in overcoming challenges, and the heightened difficulty provides a sense of achievement when they succeed. This balance between challenge and entertainment is essential for maintaining player interest and fostering a rewarding gaming environment.

For cooperative games, adding more players can enhance teamwork and collaboration, providing a different kind of satisfaction. The game becomes more deterministic as players can rely on each other to achieve common goals, reducing individual pressure while increasing collective enjoyment. The shared experience of working together towards a common objective can be highly rewarding and can strengthen the social bonds among players. However, if the number of players becomes too large, the game may become too easy and players might feel disengaged due to the reduced individual contribution. A balance must be struck to ensure that each player still has a meaningful role. If the game becomes too easy and predictable, it may lose its appeal and fail to challenge or engage the players effectively.

Overall, increasing the number of players can significantly enrich the gaming experience by introducing a blend of challenge, unpredictability, and social interaction. This balance is key to creating engaging and enjoyable games that cater to a wide range of player preferences and keep them coming back for more.

7.1.4 Differences between pressure and mass in motion in mind

Previous works have defined mass m as the level of challenge or difficulty in games. The m depends on the game's success rate or velocity v as $m + v = 1$ according to the zero-sum assumption from the motion in mind theory. The difficulty of the game from m stems from the opponents' scoring rate.

The proposed pressure is evaluated using the density of the players, which is evaluated using the number of players divided by the total area of the playing field. Pressure is greatly influenced by the density of players when compared to the velocity v of the game. Higher density signifies that players have a lower degree of freedom and fewer choices when making decisions, leading to a riskier play style.

The key difference between mass and pressure lies in the origin of the challenge they represent in a game. Mass depicts the inherent difficulty associated with the physical or mechanical aspects of the game, such as scoring points or overcoming obstacles. It reflects how challenging the game's fundamental mechanics are and how much effort is required to achieve success. A high-mass game is characterized by its stochastic nature, meaning it is less predictable and more reliant on chance. In such games, players find it difficult to consistently earn points or gain an advantage over their opponents due to the complex and variable nature of the challenges they face.

Pressure, on the other hand, relates to the psychological challenge imposed by the stakes of the game. It encompasses the stress and urgency players feel when the outcome of the game carries significant consequences. In a high-pressure game, the need to perform well is heightened, often leading players to take riskier moves to gain an advantage over their opponents. This pressure can stem from various sources, such as limited time, high stakes in competitive settings, or the critical importance of specific moments within the game. The subjective feeling of increased difficulty under pressure is due to the players' heightened emotional and cognitive state, which can impact their decision-making and performance.

For example, in a high-mass game like a challenging platformer, the difficulty comes from the precise timing and skill required to navigate obstacles and reach the goal. The unpredictable elements, such as random enemy movements or environmental hazards, add to the stochastic nature of the game, making it less deterministic and more reliant on the player's adaptability and quick reflexes.

In contrast, a high-pressure game like a competitive sports match or a crucial final round in an e-sports tournament amplifies the stakes, forcing players to make split-second decisions and take bold actions to outmaneuver their opponents. The pressure of the situation can lead to a heightened sense of challenge, as the players must manage their stress and maintain their composure to succeed.

In summary, mass and pressure define different dimensions of challenge within a game. Mass represents the intrinsic difficulty of the game's mechanics, characterized by its stochastic nature and the effort required to achieve success. Pressure, on the other hand, arises from the psychological stakes of the game, leading to riskier decisions and a heightened sense of difficulty due to the emotional and cognitive demands placed on the players. Balancing these two elements is crucial for creating engaging and challenging gameplay experiences that cater to a wide range of player preferences.

7.1.5 Emotional link to motion in mind

Several experiments were conducted to collect data and explore the possible connections between motion in mind and our emotions. Accurately analyzing a person's emotional changes is challenging, so this dissertation recorded respondents' heart rates to explain emotional changes while playing games during the experiments. Two games were chosen as the testbed: Genshin Impact and Overcooked! 2.

An online gacha simulator for Genshin Impact was utilized because the actual game would be too expensive for extensive testing. Respondents played the gacha simulator while their heart rates were monitored to study their behaviors and emotional responses. The data showed that most respondents experienced increased heart rates when they obtained a rare item from the gacha, indicating excitement and anticipation. Survey results further revealed that respondents new to gacha games were more positively inclined toward the experience compared to those who regularly played gacha games. Additionally, half of the respondents exhibited impulsive behavior, often not remembering how much they spent during the experiment. Online surveys supported this trend, indicating that many players act impulsively when engaging with gacha games.

Experiments with Overcooked! 2 demonstrated that fully cooperative games tend to feel less stressful with more players. Observations showed that the game's velocity increased as the number of teammates increased, indicating that players felt more relaxed due to easier task division, leading to a less challenging game. Heart rate readings corroborated this, generally decreasing when playing with more players. Another notable trend was the spike in heart rates during the final few seconds of the game. This spike is likely due to the game's increased tempo and the rush to complete tasks, causing time-stress and observable pressure in heart rate readings.

In summary, these experiments revealed significant insights into the emotional impacts of different game dynamics. In Genshin Impact, the thrill of obtaining rare items from gacha pulls heightened players' heart rates, especially among those new to the gacha system. In contrast, Overcooked! 2 showed that cooperative play with more participants reduced overall stress and heart rate, with the exception of the final moments of play, which induced a stress-related heart rate spike due to time constraints. These findings contribute to understanding how different game mechanics and player interactions affect emotional responses and physiological changes.

7.2 Concluding Remarks

The findings from this dissertation have given some insights into why some games could have tendencies for addiction. The number of attempts for a game is an important concept to consider as games like gacha are short duration wise but become addictive after η number of attempts. The border between games and gambling would help in creating a more ethical environment for video games in the future and better rate curate games for people of all ages.

The formulation of density and pressure using motion in mind would also explain why games feel subjectively difficult despite their m or v remaining the same. The added pressure due to a lesser freedom of movement promotes risky play from players, leading to a more intense game from the viewer's perspective. By studying badminton matches, it can be observed that similar variants have almost identical velocity v and reward frequency N. Hence, we conjectured that games are categorized by their velocity v, such that games give familiar feelings when their velocity is similar. Findings from MOBA games showed how pressure is favorable in the genre, as all popular game modes have higher pressure and densities.

Experiments carried out throughout this dissertation also showed possible connections between motion in the mind and our emotions. A study done on Genshin Impact's gacha showed that the respondents' heart rates often increased whenever they obtained a rare item from the gacha due to excitement and anticipation of the results. The study on Overcooked! 2 also showed how players feel more relaxed as seen by the lower average heart rate reading when having more teammates in a cooperative game setting. We also found some relationship between time-stress and our emotions as players show an increase in heart rate during the closing phases of the game.

7.3 Future Works

Future research endeavors could delve deeper into manipulating the probabilities associated with gacha rewards to explore their impacts on respondents more comprehensively. In the current dissertation experiment, the probabilities and pity counter remained unchanged; rather, data was gathered using a simulated gacha system based on Genshin Impact.

By adjusting the probabilities of obtaining different rarity levels or modifying the pity counter thresholds, researchers could investigate how these alterations affect player behavior, emotional responses, and overall satisfaction. For instance, varying the likelihood of obtaining rare items could elucidate the thresholds at which players perceive rewards as fair or desirable, influencing their engagement and spending patterns within the game. Moreover, exploring different configurations of gacha mechanics could shed light on how players perceive risk and reward in gaming contexts. By systematically adjusting these variables, researchers can discern optimal design strategies that balance player enjoyment with ethical considerations surrounding gambling-like mechanics.

Another limitation surfaced due to the fact that participants in the study did not use real money during the experiment, which may have diminished their sense of emotional attachment or loss when engaging with the gacha system. This absence of real financial risk could potentially impact the findings, as the psychological and emotional dynamics of gambling—where the stakes involve actual monetary loss or gain—are not fully replicated in this simulated setting.

The experience of real gambling involves heightened emotional responses, ranging from excitement and anticipation to disappointment or satisfaction based on the outcome. These emotional states are closely tied to the risk of financial loss, which intensifies the engagement and psychological impact of the activity. In our study, by using an online simulator instead of real-money transactions, participants may not have experienced the same emotional intensity or attachment to the outcomes of their gacha pulls. This could influence their decision-making processes and overall behavior during the experiment, potentially affecting the validity and generalizability of the results.

We aim to refine our study design to further explore the intricate relationship between gacha mechanics and human emotions. This includes considering ways to incorporate real-money transactions or other forms of incentivization that align more closely with the emotional stakes of traditional gambling. By doing so, we can better understand how these emotional responses influence player behavior, engagement levels, and the ethical considerations surrounding gacha mechanics in gaming.

Ultimately, by addressing these methodological challenges and refining our approach, we seek to deepen our insights into how gacha systems interact with human emotions. This research not only contributes to the academic understanding of gaming psychology but also informs practical implications for game developers and policymakers striving to create more responsible and engaging gaming experiences.

Soccer simulations could also be used to study the relationship between the number of players and the size of the field to identify the influence of pressure on the game's outcome. Simulation results could further help refine the formulation of pressure as proposed in this dissertation. Furthermore, it could be possible to find the ideal size of soccer with respect to the number of players and the field size.

Current formulations of pressure primarily focus on spatial factors, such as the density of players or the physical constraints within a game environment. However, future research could significantly broaden our understanding by exploring additional dimensions of pressure, particularly those related to time and skill.

Time pressure, for example, plays a critical role in many competitive and cooperative games where players must make decisions quickly under limited time constraints. The urgency created by time pressure often intensifies the emotional and cognitive demands on players, influencing their strategies and performance outcomes. Understanding how different levels of time pressure impact gameplay dynamics and player experiences could provide valuable insights into optimizing game design for engagement and challenge. We saw possible influence of time pressure in the experiment carried out for Overcooked! 2 which showed an increase in heart rate during the final few seconds of the game.

Skill-based pressure is another crucial aspect that deserves deeper exploration. This form of pressure arises from the need for players to demonstrate proficiency in executing specific techniques, strategies, or maneuvers within the game. Skill-based pressure can vary depending on the complexity of the game mechanics and the level of expertise required. Examining how skill-based pressure affects player behavior, motivation, and overall game satisfaction can inform strategies for balancing difficulty and enjoyment in game development.

Moreover, integrating these diverse forms of pressure into a comprehensive framework could enhance our ability to analyze and predict player responses across various gaming contexts. By studying spatial, temporal, and skill-related pressures in tandem, researchers and developers can gain a more nuanced understanding of how these factors interact to shape player experiences and outcomes.

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Appendix A: Online Questionnaire for Gacha

Survey on Gacha Gaming Habits

Hello! I'm a PhD student from Japan, majoring in Game Informatics. Currently, we are doing a research on the popularity of Gacha games, as its becoming more mainstream. Various research has been done on why players spend in games, but we would like to find out Gacha habits in particular.

No personal information will be recorded, and everything is completely anonymous. This survey should take less than 5 minutes to complete.

Thank you in advance for your cooperation!

* Indicates required question

1. I understand the purpose of the survey and I agree to to participate in the survey. *

   Mark only one oval.

   - Agree
   - Disagree

User Demographics and Preliminary Questions

This section helps to classify respondents into groups, allowing us to discover patterns easier.

2. Please select your age group *

   Mark only one oval.

   - Below 18 years old
   - 18 to 25 years old
   - 26 to 30 years old
   - 31 to 35 years old
   - Above 35 years old
   - I prefer not to say

3. Which region do you live in? *

Mark only one oval.

- Americas (North America, South America, Central America, Caribbean)
- Asia Pacific (Central & South Asia, Northeastern Asia, Southeastern Asia, Australia and Oceania)
- Europe (Northern Europe, Southern Europe, Eastern Europe, Western Europe)
- Middle East/Africa (Middle East, Northern Africa, Southern Africa)
- I prefer not to say

4. Do you play any Gacha games? *

Mark only one oval.

- Yes
- No

5. Do you play Genshin Impact? *

Mark only one oval.

- Yes *Skip to question 6*
- No *Skip to question 18*

Genshin Gacha Habits

This section is focused on collecting the habitual data for Genshin Impact players.

6. Which of the statements below fits you? *

Mark only one oval.

- ( ) I am a Free-to-play player
- ( ) I am a small spender (Only Welkin and/or Battle pass)
- ( ) I occasionally buy crystal packs to get certain limited character/weapon
- ( ) I spend regularly to get the limited character/weapon
- ( ) I prefer not to say

7. Which of the following are the reasons you pull for a character/weapon? *

Check all that apply.

- [ ] The character/weapon is strong
- [ ] The character/weapon appeals to me aesthetically
- [ ] The character/weapon would help me complete my team
- [ ] I just want to collect all character/weapon in the game
- [ ] I like the character's personality
- [ ] The character/weapon was nice in the story quest
- [ ] The character/weapon is fun to play
- [ ] Other: ____________________

8. When do you decide to pull in the gacha? *

Choose one that fits the most to you or happens majority of the time.

Mark only one oval.

- ( ) I really want the character/weapon
- ( ) I just want to try my luck
- ( ) I got some gems/fates, so I would like to use them
- ( ) Other: ____________________

9. Have you impulsively played a gacha before? *

Example: Randomly pull from the gacha banner without expecting anything.

Mark only one oval.

- Yes
- No
- Maybe

10. How many pulls do you make at a time before you stop? *

Answer based on what you would do on average or your most common habit of pulling.

Mark only one oval.

- Less than 10 pulls (Using up remaining fates/gems)
- 10 pulls
- 20 pulls
- 30 pulls
- 50 pulls
- I pull until I get a 5-star
- I pull until I get what I wanted
- Other: ____________________

11. Do you think you are lucky? *

Mark only one oval.

- Yes
- No
- Maybe

12. Have you ever felt regret or dissapointment when pulling for character/ weapon from the gacha? *

Mark only one oval.

- Yes
- No
- Maybe

13. If you do spend money on gacha games, do you feel regret or dissapointment when you have to spend money to get a character/weapon? *

Mark only one oval.

- Yes
- No
- I don't spend on gacha games

14. Do you think social aspect of gacha influences your spending habits? *

Example: All you friends or community members have a certain character/weapon but you dont. This pressures you into pulling for that character/weapon as well.

Mark only one oval.

- Yes
- No
- Maybe

15. Have you ever spend more than what you planned for in a gacha game? *

Mark only one oval.

- Yes
- No
- I don't spend on gacha games

16. On a scale of 1 to 5, how important do you think the element of chance is in making gacha fun? *

Mark only one oval.

	1	2	3	4	5	
Not	◯	◯	◯	◯	◯	Very Important

17. Do you also play other Gacha games? *

Mark only one oval.

- ◯ Yes
- ◯ No

Gacha Habits

This section is focused on collecting the habitual data for gacha players.

18. Which of the statements below fits you? *

Mark only one oval.

- ◯ I am a Free-to-play player
- ◯ I am a small spender (Only spend less than $10 a month)
- ◯ I occasionally buy packs to get certain limited items
- ◯ I spend regularly to get all the limited items
- ◯ I prefer not to say

19. Which of the following are the reasons you pull for an item? *

Check all that apply.

- [ ] The item from the gacha is strong
- [ ] The item from the gacha appeals to me aesthetically
- [ ] The item from the gacha would help me in progressing in the game
- [ ] I just want to collect all the items in the game
- [ ] Other: ______________________

20. When do you decide to pull in the gacha? *

Choose one that fits the most to you

Mark only one oval.

- ( ) I really want the item from the gacha
- ( ) I just want to try my luck
- ( ) I got some of the gacha currency from playing the game, so I would like to use them
- ( ) Other: ______________________

21. Have you impulsively played a gacha before? *

Example: Randomly pull from the gacha banner without expecting anything.

Mark only one oval.

- ( ) Yes
- ( ) No
- ( ) Maybe

22. How many pulls do you make at a time before you stop? *

Answer based on what you would do on average.

Mark only one oval.

- Less than 10 pulls (Using up gacha currency earned from playing)
- 10 pulls
- 20 pulls
- 30 pulls
- 50 pulls
- I pull until I get a rare item
- I pull until I get what I wanted
- Other: ______________________

23. Do you think you are lucky? *

Mark only one oval.

- Yes
- No
- Maybe

24. Have you ever felt regret or dissapointment when pulling for items from the gacha? *

Mark only one oval.

- Yes
- No

25. If you do spend money on gacha games, do you feel regret or dissapointment when you have to spend money to get the items? *

Mark only one oval.

- Yes
- No
- I don't spend on gacha games

26. Do you think social aspect of gacha influences your spending habits? *

Example: All you friends or community members have a certain item but you dont. This pressures you into pulling for that item as well.

Mark only one oval.

- Yes
- No
- Maybe

27. Have you ever spend more than what you planned for in a gacha game? *

Mark only one oval.

- Yes
- No
- I don't spend on gacha games

28. On a scale of 1 to 5, how important do you think the element of chance is in making gacha fun? *

Mark only one oval.

	1	2	3	4	5	
Not						Very Important

29. How many gacha are you playing currently? *

Mark only one oval.

- ( ) Just one
- ( ) Two or more

Appendix B: Post Experiment Survey for Gacha Experiment

Post Experiment Survey on Gacha Gaming Habits

Hello! I'm a PhD student from Japan, majoring in Game Informatics. Currently, we are doing a research on the popularity of Gacha games, as its becoming more mainstream. Various research has been done on why players spend in games, but we would like to find out Gacha habits in particular.

No personal information will be recorded, and everything is completely anonymous. This survey should take less than 5 minutes to complete.

Thank you in advance for your cooperation!

* Indicates required question

1. Please select your age group *

Mark only one oval.

- Below 18 years old
- 18 to 25 years old
- 26 to 30 years old
- 31 to 35 years old
- Above 35 years old

2. Have you played any Gacha games previously? *

Mark only one oval.

- Yes
- No

3. Have you played a Gachapon machine before? *

Gachapon machine = Toys Capsule machine

Mark only one oval.

- Yes
- No

4. If you answered yes previously, do you find any similarities between Gacha in games and Gachapon machine?

Mark only one oval.

- Very similar
- Slightly similar
- No similarities
- I don't know

5. During the experiment, how did you feel? *

Example: Nervous, Excited, Dissapointed etc.

____

6. During the experiment, why did you choose the character you wanted? *

Mark only one oval.

- The design looked really nice
- The character looked strong
- I know the character and I wanted it
- No particular reasons

7. During the experiment, did you get what you wanted? *

Mark only one oval.

- Yes
- No

8. During the experiment, do you remember how much you spent? Please write your estimated amount. *

____

9. If it was real money, can you see yourself spending that amount? *

Mark only one oval.

- Yes
- No

10. Overall, do you think you were lucky? *

Mark only one oval.

- Yes
- No
- Maybe

11. On a scale of 1 to 5, how important do you think the element of chance is in making gacha fun? *

Mark only one oval.

	1	2	3	4	5	
Not	○	○	○	○	○	Very important

12. If you have any comments or feedback for the experiment, please leave them down here.