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A Paradigm Shift from Optimal Play to Mental Comfort: A Perspective from the Game Refinement Theory

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ABSTRACTS

The game refinement theory focuses on the game designer perspective, where its application in various types of games provides evidence of the occurring paradigm shift. Utilizing the logistical model of game outcome uncertainty, it provides a platform for incorporating gamified experience observed in games to be adopted in domains outside of game while retaining the context of the game. Making games as a testbed, the implications of the game refinement theory have been observed in the educational and business perspective, while further explored its utility in interpreting some states of the human mind. In addition, a holistic view of design in games and in the real-world environments was discussed, where the prospects of the game refinement theory were also highlighted.

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1. INTRODUCTION

Originated from the idea of the existence of mixed strategy equilibria in two-person zero-sum games (Neumann, J. V., 1928), game theory (GT) had been widely utilized as a useful tool in many fields such as economics, political science, psychology, logic and biology. However, the GT focuses on the perspective of the player's side. Looking from the perspective of the designer's side, the game refinement theory (GR) is a unique theory derived from the classical game theory. The GR is defined as the measure of attractiveness and the sophistication of games based on the game outcome uncertainty (Panumate et al., 2015).

Previous works such as (Diah, et al., 2014), (Xiong, S et al., 2014), (Xiong, S., and Iida, H, 2014), (Panumate et al, 2015), focused on various spectrum of games such as sports, board games and video games. It shows that the game refinement values of those popular games support the previous assumptions of a balanced range of game refinement value which is GR ∈ [0.07,0.08] (Xiong, S et al., 2014). While many research works have been done using GR that focuses on game entertainment of many game-related domains, there had been limited applications to the real-world settings.

The goal of this paper is to highlight the current change of paradigm in game design from the lens of the GR framework, where the shift of focus from making an optimal play to providing mental comfort has been observed from recent works. The organization of the paper is as follows. The game refinement theory is described in details from the perspective of continuous game (such as sport games), discrete game (turn-based and board games), and mixture of both perspectives (Section II). Then, its application in the context of education and business are investigated where GR theory is applied in relation to current concept of edutainment and gamification in the real-world settings (Section III). Next, in-depth interpretation of the GR theory with respect to the perceived nature of human mind, specifically on understanding the sense of curiosity and boredom, is investigated (Section IV). In addition, general discussion on the overall perspective of the GR theory is given in Section V while Section VI concludes the paper.

2. GAME REFINEMENT THEORY

A personal decision process in mind typically involves considering all possibilities of available options which then are reduced to only a single decisive solution. This process commonly involves both the aspects of skill and chance. In a case of a board game, an experienced player may identify only a few decent moves out of all possible instances (Iida H., 2008). However, only one solution has to be decided as the final solution. This idea has been expanded to establish the mass-in-mind model, which being integrated into the game refinement model. Fig. 1 presents the generic selection process in a player's mind.

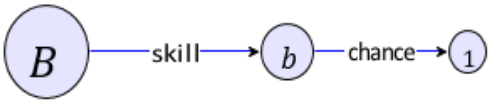

Fig. 1. The player decision selection process

While all possible instances are relatively large, some of them are out of an experienced player's consideration

as they might lead to deficiency or failure. The effective branching factor b of a player is a subset of the branching factor, in which only acceptable solutions are concerned. **Effective branching factor** of a player is the number of instances, which are satisfyingly perceived by that player in a single decision. **Reduction rate of branching factor** (say α) for the minimax-based game tree where B and b ($1 \leq b \leq B$) is the average branching factor and the effective branching factor, respectively. Thus, α is defined by (1). The effective branching factor b is significantly smaller than the branching factor B but not underneath 1, so $1 \leq b \leq B$.

$$\alpha = \frac{b}{B} \tag{1}$$

A. A Game Progress Model

The general game refinement model was proposed based on the concept of game information progress, where the gap between boardgames and sports games was bridged (Sutiono et al., 2014, Iida, H., 2018). The "game progress" can be one of two things. One of it is the game speed or scoring rate. Meanwhile, another can be the game information progress which focuses on the game outcome. Game information progress presents the degree of certainty of the game's results in time or in steps. Having the complete information on the game progression (i.e. after its conclusion), the game progress x(t) will be given as a linear function of time t with $0 \leq t \leq tk$ and $0 \leq x(t) \leq x(tk)$, as shown in (2).

$$x(t) = \frac{x(t_k)}{t_k} t \tag{2}$$

Here, tk and x(tk) corresponds to the end of task and the goal to achieve in task, respectively. (2) implies that goal of the task under consideration must be achieved within the time tk, meanwhile it may not be shorter time than tk (Iida H., 2018). Under the given time constraint (Fig. 2) that task should be completed within the time t with $0 < t < tk$ where $x(t) = x(tk)$. However, the game information progress given by (2) is unknown during the in-game period since $t < tk$. The presence of uncertainty during the task, often until the final moment of the task, would cause the task progress to be exponential. Hence, a more realistic model of information progress of a given task is given by (3).

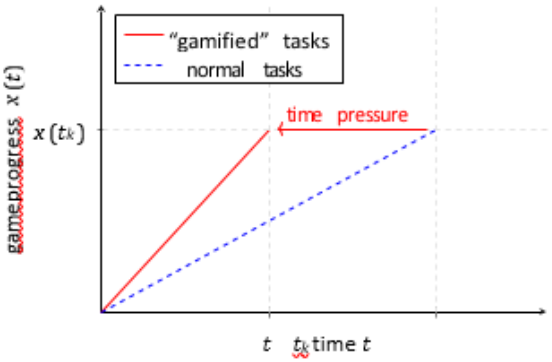

Fig. 2. An illustration of normal activity becomes gamified under a time constraint (adapted from (Iida H., 2018).)

$$x(t) = x(t_k)\left(\frac{t}{t_k}\right)^n \tag{3}$$

Here $n \in \mathbb{R}$ stands for a parameter related to the degree of difficulty of completing the task. In the context of (3), lower n implies a very boring task while higher n would imply higher difficulty of completing the task. By deriving the task's information

progress, when $n \geq 1$, the "velocity" in the sense of information dynamics can be obtained in (4).

$$x'(t) = \left(\frac{x(t_k)}{(t_k)^n}\right) t^{n-1} n \quad (4)$$

When $n \geq 2$, the second derivative of the task's information progress or "acceleration" in the sense of information dynamics, which obtainable by deriving (3) twice. Then, solving it at $t = t_k$, (5) was obtained.

$$x''(t) = \left(\frac{x(t_k)}{(t_k)^n}\right)(t_k)^{n-2} n(n-1) = \left(\frac{x(t_k)}{(t_k)^2}\right) n(n-1) \quad (5)$$

The game information progress modelled in (5) was assumed to be the abstraction of the information in a human brain. As the physics of information in the brain is yet to be discovered, it is likely that the acceleration of information progress is subjected to the forces and laws of physics. Too little game information acceleration may be trivial for human observers and players to compute. In contrast, too much game information acceleration would cause frustration, overwhelming and even incomprehensible to humans.

Representing $x(t_k)$ and t_k as G and T respectively, the GR formulation in its root square is given in (6). Therefore, increases in the value GR is expected to increase the excitement of the game, due in part to the uncertainty of game outcome. Application of the GR measure in popular sports is given in Table 1.

$$GR = \frac{\sqrt{G}}{T} \quad (6)$$

Table 1. The *gr* measure for popular sport games (Takeuchi J., 2014, Ramadhan et al.,2015, Panumate, et al., 2017).

Games	$x(t_k)$	t_k	GR
Basketball	36.38	82.01	0.073
Soccer	2.64	22.00	0.073
Volleyball (side-out: 15pts)	15	52.52	0.121
Volleyball (rally point: 30pts)	30	53	0.104
Volleyball (rally point: 25pts)	25	44	0.114
Table tennis (pre-2000)	57.87	101.53	0.075
Table tennis (post-2000)	54.86	96.47	0.077
Badminton (side-out)	30.07	45.15	0.121
Badminton (current)	46.34	79.34	0.086
Baseball (major league)	4.57	34.23	0.062

B. A Board Game Model

For a board game, the definition of branching factor is the amount of all possible instances in a single decision while the game length is the number of steps from the beginning to the ending or the resignation. A game tree is constructed by recursively attaching all possible transitions to the initial position (Xiong, S et al., 2014) Let B and D be the average branching factor and the average game length respectively. A single decision can be illustrated in Fig. 3. By considering the geometry, the distance d is obtained by $\sqrt{\left(\frac{B}{2}\right)^2 + 1}$ according to the Pythagorean theorem (Maor E., 2019).

However, one is much smaller than B and left from the consideration.

Hence, the distance d becomes $\frac{B}{2}$. Assuming the outcome continuously becomes evident, the model of game progress $x(t)$ is determined by the proportion of the d and the game length D. Therefore, the model of game progress becomes $x(t) = \frac{t}{D} \times d = \frac{Bt}{2D}$. In general, (7) was obtained.

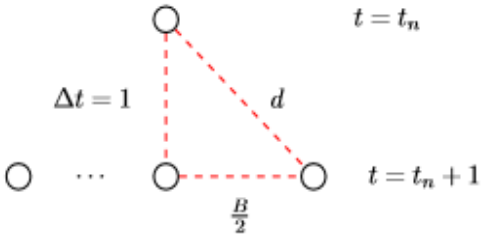

Fig. 3. A Generic Single Decision in a Game Tree

The value of c and $n(n-1)$ in (5) had been discussed in previous works (Xiong et al., 2017) Following the game progress model, the uncertainty of the outcome renders the $x(t)$ exponential. Therefore, the more realistic model of game information progress becomes (8).

Then, similarly in obtaining the game refinement measure GR of the game progress model, the GR of the board game model is obtained by deriving (8) twice and taking its root square form, as shown in (9). Application of the GR measure in popular board games and other multiplayer games is given in Table 2. If the same model were also extended to the domain of the video games, then the B and D corresponds to the average number of successful attempts and average number of attempts per game, respectively. As such, the GR measure of some popular video games is also provided (Table 3).

$$x(t) = B\left(\frac{t}{D}\right)^n \tag{8}$$

$$GR = \frac{\sqrt{B}}{D} \tag{9}$$

Table 2. The *gr* measure for popular board and other multiplayer games (Iida et al., 2004, Xiong et al., 2014, Panumate et al., 2016, Panumate et al., 2017)

Games	$x(t_k)$ or B	t_k or D	GR
UNO	0.976	12.684	0.078
RoShamBo	3	1.5	1.155
UFO catcher	0.967	13.30	0.074
Western Chess	35	80	0.074
Chinese Chess (Xiangqi)	38	95	0.065
Japanese Chess (Shogi)	80	115	0.078
Go	250	208	0.076
Mah Jong	10.10	39.56	0.078

Table 3. The *gr* measure for popular video games (Xiong et al., 2014, Panumate et al., 2016, (Punyawee et al, 2016, Xiong et al., 2017)

Games	$x(t_k)$ or B	t_k or D	GR
DoTA v6.48	69.2	110.8	0.075
DoTA v6.64	68.4	110.4	0.075
DoTA v6.80	68.6	106.2	0.078
Snake AI (Wall)	4.44	34.98	0.060
Snake AI (No wall)	2.18	17.03	0.087
Starcraft 2 (Terran)	1.64	16	0.081
Starcraft 2 (Protoss)	1.55	18	0.069
Starcraft 2 (Zerg)	1.61	20	0.082
King of Fighters 98	14.6	36.7	0.104

C. A Swing Model

The game progress model supports only a game with uniformed scoring rate, e.g., Soccer. In Soccer, a successful shoot is particularly challenging to obtain and regarded as one score. Supposing that the gained score is multiplied, the measure of game progress model may alter, but the real essence of the game remains unchanged (Kananat et al., 2016). However, SCRABBLE players earn several marks in turn. This incident happens in a case of the games with the non-uniformed scoring system. Therefore, SCRABBLE has non-uniformed scoring rate and not directly compatible with the game progress model.

Instead, the swing model is introduced by defining swing turnover as a state transition in mind during the game progress among some possible states. In a game with non-uniformed scoring rate, the average amount of swing turnover S is proposed as a measure for counting the actual successful shoot. Although the transition among possible states may differ for a different domain, we consider two cases: advantage and disadvantage. It is rumored that maximizing own profit while minimizing others have been the general principle of the intelligent decision maker (Harsanyi et al., 1988). Obtaining the highest score is the goal of playing SCRABBLE.

In each step, players are taking their turn to attempt to have the advantage over the opponent, which is considered as the actual successful shoot G, if successful. Let D_0 be the average turn that player potentially turns the swing. Due to difficulty in measuring D_0, the game length D is used as its approximation. The game refinement GR of the swing model is obtained by (10).

$$GR = \frac{\sqrt{S}}{D_0} \approx \frac{\sqrt{S}}{D} \tag{10}$$

Swing model is an approximation of game progress model as an exciting game when there is a proper amount of swing turnover as opposed to a single-sided game (Kananat et al., 2016). The game refinement measure reflects the balance between player's strength and surrounding randomness in a game considered (Xiong et al., 2017) While a superior value implies that a chance becomes a stronger factor, a game with an extreme game refinement measure might overwhelm a player with the information, which results in frustration. As such, the GR measure based on (10) for SCRABBLE based on 20,000 match records from cross-table.com is provided (Table 4).

Table 4. Game Refinement Value of Scrabble Game

Average number of swing turnovers (S)	5.096
Average number of total rounds (D)	27.145
Total match record data	23,164
Game refinement value (GR)	0.083

3. GAME REFINEMENT THEORY MEETS THE REAL-WORLD

In a real-world setting, design of game elements is highly dependent on the context of interest. Incorporating

game elements in education leads to an innovative teaching-learning methodology known as "edutainment", which involves the mixture of entertainment and education or marriage of education with entertainment (Aksakal N., 2015, Agarwal S et al., 2019).

Such methodology may be inclusive of different levels of interactions, motivations, experiences, and mental acceptance in the educational process through elements perceived to be entertaining, commonly found in games. The players of such games benefited from collaborating among themselves both inside the amusement condition (e.g. through networking on the web-based groups) and around it (e.g. through sharing game-related data and assets) (Agarwal S et al., 2019).

In a broader sense, adopting game design elements in nongame contexts is a popular concept known as "gamification". The concept of "gamification" was first launched in 2008 in a blog post by Brett Terrill (Terrill, B. 2008). He described gamification as taking the game mechanics and applying them to other web properties to increase engagement (Huotari, K., and Hamari, J., 2012), which becomes a widespread industry use (Deterding, S et al., 2011). Gamification can be defined as adopting game design elements in non-game contexts, without changing the existing practice of that context, in order to improve user experiences in term of engagement and learning, employee recruitment and evaluation, ease of use and encourage physical exercise (Huotari, K., and Hamari, J., 2012, Huynh, D et al., 2016). Gamification also enhances the player's ability to understand a specific domain of studies such as language learning or music.

Although there can be many methods to edutainment and gamification, the GR theory provides an alternative method to both concepts from the educational and business standpoint. Note that the GR theory is adopted with only minor changes on defining the context of the "game progress" with respect to the application domain. The GR value still retains its original intention, which is the measures of attractive and sophistication in game design.

A. Educational perspective

Application of the GR measure with respect to educational perspective had seen some potentials, which demonstrated in two type of edutainment games: MindSnacks and Duolingo3. These games were selected due to several reasons. Firstly, both of the games were language learning platforms. Secondly, they shared similarity in term of the milestone technique used as part of the game elements in the learning process. Thirdly, both of them adopted learning methods that measurable in number (lessons or tasks).

MindSnacks are specialized games for individual languages including Chinese, Japanese and several European languages. It spreads learning lessons such as vocabulary, spelling, and grammar across nine different mini-games with their own

hand-drawn art. A user is first given three available minigames to start while the rest is unlocked when the user reaches a certain number of levels for each. By adopting the milestone technique used by game designer, there is a certain number of levels that require completion (by performing several tasks) before unlocking the mini-game in a particular milestone (Izzyann, F et al., 2018).

Therefore, Lv and T is the average number of levels required to unlock the mini-games and the average number of tasks, respectively. To calculate the GR value, with reference to (6), let G and T equals to Lv and T, respectively, which corresponds to the progress model for MindSnacks.

Meanwhile, Duolingo is a publicly available gamified free language-learning platform since 2012 which is created by professor Luis Von Ahn and his graduate student Severin Hacker. As of April 2016, it offers 59 different language courses across 23 languages. Duolingo is a product of gamification, where game elements are utilized to create enjoyment in the learning process. In a language course, the goal is to complete a study by getting all badges in the skill-tree. To achieve a badge, users must complete all lessons in a skill. As such, the game progress of Duolingo language course can be measured by skills. Let S and L be the average number of skills and the average number of lessons in the same language courses, respectively. Therefore, with reference to (6), the S and L in Duolingo are equal to the G and T, respectively, in order to calculate its GR value.

A comparison between MindSnacks and Duolingo on Japanese language course using the GR measures is given in Table V. Referring to the previous work, the Spanish language course of Duolingo falls onto the range of GR ∈ [0.020,0.026] which is reasonable for the serious-like game environment (Huynh, D et al., 2016). Similar tendency occurred in both platforms for the Japanese language course where the GR value for each milestone decreases gradually. Also, there is a big gap between GR-value at the first milestone of both platforms due to the big difference of the average number of tasks or lessons needed to complete it. This difference in value indicates that Duolingo is much more attractive to beginner learner while MindSnacks requires learner with strong motivation since it's much difficult to beginner.

Table 5. Game Refinement Measures of Mindsnacks and Duolingo on the Japanese Language Course

MindSnac				Duoling			
Milestone	*Lv*	*T*	*GR*	Milestone	*S*	*L*	*GR*
Totems	3	5	0.35	1	7	34	0.08
Blooms	6	17	0.14	2	15	66	0.06
Stacks	10	37	0.09	3	27	130	0.04
Bubbler	15	85	0.05	4	40	185	0.03
Dam Builder	21	141	0.03	-	-	-	-

L_v: average number of levels required to unlock the mini-games; *S*: average number of skills; *T/L*: average number of tasks/lessons;

The GR value for both MindSnacks and Duolingo started to decline in the

subsequent milestones as the learner progresses, where both resulted in the same GR value of 0.03 at the fifth and fourth milestone, respectively. Additionally, MindSnacks has one extra milestone compared to Duolingo, making MindSnacks much more appealing towards serious but casual learners. In contrast, Duolingo may appeal to additional game elements (such as winning streaks (Huynh, D., and Iida, H., 2017) to retain learner's motivation since only small sense of achievement can be elicited (from the small changes of the GR value between milestones). As such, a longer milestone may effect users' feeling of achievement. Finally, observing the accumulated tasks or lessons at the end of each milestone, MindSnacks had a lower *T* value compared to *L* value of Duolingo. This means the enjoyment and motivation of finishing the tasks or lessons inversely proportional to its number.

B. Business Perspective

Gamification employs game design elements which are used in non-game contexts to actively improve the user's engagement by applying game-based thinking through badges, rewards programs and points (Zuo, L., and Iida, H., 2017). There are three main ingredients (but not limited to) that offer gamification in various real-world application; game element, game design, and non-game context.

Game elements involves building some form of service which utilized usage of bits and pieces of games (i.e. interactive graphical user interface) to improve the user experience. Meanwhile, game design is the inclusion of game playing feeling through game elements such as the points and tiers system which organized systematically and encourage enjoyment in such activity. Finally, non-game context can be translated to anything other than the game in which the objective is outside of the game; thus, related to their needs or business. With respect to the GR theory application and gamification in the business perspective, two types of business strategies were analyzed from the customer's point-of-view; sales promotion and loyalty programs.

1) "Discount" Sales Promotion: The money saved by the sales promotion 'discount' is considered beneficial to the customers. This is because customers have little knowledge and interest about the cost of a product of interest (Zuo, L., and Iida, H., 2017). However, they would care more about the price of the product (i.e., how much money can be saved by the discounting). If the rate of discount is reasonable from the perspective of customers, the "game of discount" would have a comfortable zone value of game refinement, similar like the sophistication of the boardgames and sports.

As such, the money saved by the sales promotion 'discount' is considered as the benefit for customers where the total benefit of the customer's shopping activity in a certain time is measurable. Based on such information, the game progress model can be constructed by two factors: the total benefit of a certain product (*G*) and the total normal price without discount (*T*). Important note is that discount in the sales promotion

typically expressed as percentage. To normalize the model in (6), we assume that the benefit of a product is ranged from 0 to 100 and the normal price is 100. Then, the model in (6) is extended to (11) that gets the GR_c of different extent of discount for customers where d stands for the discount coefficient (i.e. 10% discount equals to 0.9 discount coefficient) (Zuo, L., and Iida, H., 2017).

$$GR_c = \frac{\sqrt{G}}{T} = \frac{\sqrt{100 \times (1-d)}}{100} \quad (11)$$

It is important to identify a reasonable discount zone for customers. It is expected that lower GR would be less attractive for customers, whereas higher GR would be of some concern about quality and hard for the sustainability of seller. Two data sets were collected for the analysis. The first data set is intended to optimize the seller's total profit within a time frame using computer simulation in order to maximize total sales volume from the seller's standpoint. The second data set is collected from bestsellers (Bento Boxes & Water Bottles[4]) of a popular on-line retailers (Amazon JP[5]) which corresponds to the customer's standpoint. Then, both data set was set with a fictitious market demand of 10,000 products within a year. The total amount sale is determined by two factors: quantity and price. The discount coefficient will be changed every week and range from 0 to 1.

The demand of product follows the *F*distribution and the customers follow the Poisson distribution. Tables VI showed the discount rate by simulation and real data of Amazon JP where The discount rate of simulation is ranged from 21% off to 39% off, whereas the top sales product of Amazon JP is ranged from 42% off to 59% off. Note that the GR_c results of simulation is best for the seller but considers little about customers. However, GR_c of Amazon JP is ranged from 0.065 to 0.077, which is located in the zone value ($GR \in [0.07,0.08]$). Thus, under the assumption that the sales promotion 'discount' is a fascinating game, the simulation concerns about sustainability and Amazon JP concerns about popularity of the game.

Table 6. Discount Rate and Measures of Game Refinement (Gr_c) For Simulation, Amazon Jp, and Recommend

	Discount rate (%)	**GR_c**
Simulation	42 - 59	0.065 – 0.077
Amazon JP	21 - 39	0.046 – 0.062
Recommended	49 - 64	0.07 – 0.08

The attractiveness of games often comes within the approximate zone values ($GR \in [0.07,0.08]$) where its corresponding discount zone is ranged from 49% to 64% off (Tables 6). The essence of game refinement theory is to find a comfortable acceleration (the sense of thrill) for game players (or customers). Hence, the discount rate should not be too high. For example, too high GR_c may also cause some concern such as quality of a product of interest.

This is why some shopping festivals, like "Black Friday" in America and "1111 Shopping Festival" in China, set their discount rate 50% off since this discount rate falls on the comfortable

zone. Higher GR_c means higher entertainment impact and more popular which would be able to motivate customers to buy more. The essential idea is to offer an appropriate discount zone based on the previous knowledge of the GR theory where benefits of game thinking (such as discounting) can be adopted in the business domain.

2) Customer Loyalty Program: In today highly competitive marketplace, customer retention is an important factor for the success of businesses because the cost of finding a new customer is about 5 to 10 times more than to keep the existing one. Customer retention is defined as the activities and actions of companies and organizations to reduce the number of customer defections (Xin, O et al., 2017). Loyal customers tend to spend more (67% more than new customers) and often know exactly what they want when purchasing from a certain brand. Unfortunately, companies tend to lose around 13% of their customers every 5 years (Kumar, K., 2016).

Therefore, loyalty of a customer is critical to the sustainability of a business. Generally, loyalty program refers to a reward program offered by a business to customers who frequently make purchases (Xin, O et al., 2017). Loyalty program typically requires customers to register with their information and customers will be given a unique membership ID or physical membership card to be used when making purchases. The business owner can track behavior and history of their customer purchase in order to recognize the loyal customers and hence reward them. Meanwhile, customer engagement is further improved when the feeling of appreciation by the company is established with the customer. As such, three case studies of the customer loyalty program are analyzed using the GR theory; Starbucks loyalty program, hotel loyalty program, and frequent flyer program (FFP).

Starbucks is a fast growing coffee shop business with 7% annual growth rate (Xin, O et al., 2018). According to statistic in 2016, there is increase of 26% in profit and 11% total revenue when Starbucks introduced the "My Starbucks Rewards" program (Fisher, E., 2016). "My Starbucks Rewards" is a free loyalty program that gives exclusive member offers and allow customers to earn rewards (such as free drinks, foods and refills). Customers simply need to pay for any Starbucks product with a registered Starbucks card to earn a reward. Each time a purchase is made, customer will earn a specific amount of stars that can be redeemed for free Starbucks treat. The terms and conditions of "My Starbucks Rewards" varies according to different countries. As of 2016, the number of Starbucks licensed stores globally is ranked by Unites States (US) as the first with 5,292 stores and followed by China with a total of 1,110 stores (Xin, O et al., 2017). In order to calculate the GR value based on (6), the number of free items redeemed and total number of items consumed is represented by G and T, respectively. The evolution of "My Starbucks Rewards" since 2009, Starbucks US had continuously made minor changes on the rules in redeeming free items (assuming the average price

of a cup of Starbucks coffee which is $4 and RMB27 in US and China, respectively). Hence, the GR value of different versions of "My Starbucks Rewards" from the perspective of point system in Gold Level is analyzed (Table VII).

Table 7. Differences of "My Starbucks Rewards" In Us and China and Gr Values of Starbucks Loyalty Program (Point System) In Earning a Free Item in Gold Level Based On Versions

Country		**US**		**China**
Levels		2		3
Req. to reach/stay (Gold level)		38		47
Req. to get 1 free item (Gold level)		16		10
Year	Version	*G*	*T*	*GR*
2009	Visit-based	1	15	0.067
2012	Visit-based	1	12	0.083
2016	Spend-based	1	16	0.063

Req.: Purchase requirement in number of cups per customer

From 2009 to 2012, changes in "My Starbucks Rewards" rules increased the GR value. This means that customers in Gold Level are required to spend less for a free item redemption. On the other hand, comparing the visit-based in 2012 with the spending-based in 2016 of "My Starbucks Rewards", the GR values decreased from 0.083 to 0.063. This result may be explained by the fact that Starbucks requires its customers to spend more in order to get a free item. Before introducing the spending-based reward, customer can spend less than $4 (the average price of a cup of Starbucks coffee in 12 transactions) to earn a free item. Since Starbucks values its loyal and high-spending customer, the reward rules change so that star is earned based on amount of spending. These changes are less entertaining and more challenging for the customers whom spend minimum amount to earn stars or free items. In addition, it was found that the requirement for a customer to reach or stay in Gold Level in US is lower than in China. However, the requirement for a customer to get one free item in Gold Level is higher in US as compared to China.

Another customer loyalty program, called the hotel loyalty program, involves enticing frequent hotel guests or other business travelers to favor that particular brand or group of hotels over others when selecting a hotel (Zuo, L et al., 2018). The world's largest hotel chains, including Marriott, Starwood, Hyatt, Hilton, IHG (InterContinental) and others, all operate reward programs[1]. Hotel loyalty program usually adopted tiers system (up to four tiers) and point system (point accumulation). A newly joined customer has several benefits, such as the complimentary inroom internet access and the guarantee of the lowest rate to encourage retention in the loyalty program. Joining the scheme and staying nights in a hotel will typically accumulate points where it can be redeemed for free nights in hotels (Zuo, L et al., 2018).

Higher levels in the scheme will generally offer a combination of benefits

[1] All company names, loyalty rewards names, trademarks, and pictures are properties of their respective owners.

(i.e. complimentary room upgrades, bonus points and hotel's amenities such as conference room, lounge and other privileges). An elite status is typically reached by staying a certain number of nights say 60 or more during the membership year. The two mechanics (tiers and points) seem to be irrelevant, however, when looking back to the whole structure of the hotel loyalty program since it was found that the two mechanics are correlated with each other. The elite member could accumulate their points much faster with the additional points policy which also means that they could get more free nights (Zuo, L et al., 2017).

To calculate the GR value for hotel loyalty program of a tier system, the number of successful qualifying nights corresponds to the *G* and the total number of days within a year (365 days) corresponds to the *T*, where the result is given in Table 8. Basically, each hotel has almost the same strategy of membership management and tiers. However, Marriott hotel has a higher requirement for the silver status. It means that Marriott requires customers to spend more on its loyalty program. By observing the GR values, we may conclude that the GR value between 0.000 (become a member) to 0.027 (Platinum level) would be the activity zone for the hotel loyalty program. This means that a customer can enjoy much more only when they becomes the elite status membership. Thus, the hotel loyalty program may be recognized as a kind of skill-based games.

Table 8. Gr Measures for Hotel Loyalty Program with Focus on Qualifying Nights: Five Hotel Groups Compared

Hotel Groups	GR		
	Silver	Gold	Platinum
IHG	0.009	0.017	0.024
Hilton	0.009	0.017	0.021
Starwood	0.009	0.019	0.027
Marriott	0.014	0.019	0.024
Hyatt	0.009	0.015	0.021

Meanwhile, the points for redeeming free nights dramatically differ from the location and brands, which highlights the consideration of hotel location when applying the GR measure to different cities. Thus, three big cities were chosen: Shanghai, Tokyo, and Paris. In addition, as the GR measure requires the highest level (skillful player) to make the result more objective, the most senior membership was taken as the sample to calculate the *GR* value. As such, each member would be playing the same game. As such, the number of redeemable free nights (*G*) and the number of successful qualifying nights (*T*) is considered for the point system (Table IX). The results showed that the average price and redeem points differ based on location. However, IHG and Hilton have the same GR values regardless of the location which implies that these two hotel groups have the same strategy when dealing with the free nights. The GR value of Starwood and Hyatt slightly vary with the location. On the other hand, the result of Marriott greatly differs in location. Also, both Starwood and Marriott provide a higher game element for Shanghai

location; thus, showing that Marriott is dedicating its resources in China location by providing a more enjoyable experience in Shanghai.

Another customer loyalty program, called the frequent-flyer program or FFP, is a loyalty program offered by airlines. From a historical perspective, FFP is considered to be the world's largest gamified service (Zuo, L et al., 2017). Many airlines have FFPs designed to encourage customers to accumulate points (also called miles or segments) that redeemable for air travel or other benefits travelers can receive from the program (Zuo, L et al., 2017). The FFP first started with the "Advantage" program which was characterized by a series of inventions that improved airlines' revenue streams, increased customer recognition, reward customers for using the airline, and to promote future customer loyalty (De Boer, E. R., and Gudmundsson, S. V., 2012). Gamification of the FFP leverages the intrinsic human motivations of accumulating rewards or miles and build up the users' motivation while ensuring the engagement is continuous (Zuo, L et al., 2017). It can be defined as a service quality attribute that consists of two systems: tiers system and points system.

The tiers system is commonly represented by four levels: member, silver, gold and platinum. The tiers system is an application of progression levels or difficulty levels just as in video games. Depending on the airline's regulations, different statuses enjoy different levels of rewards, additional points, priority check-in and lounge access. The membership requirement of tiers system of four Chinese FFPs is given in Table X. Meanwhile, the points system (or miles) is a type of virtual currency used predominantly within the game world (Zuo, L et al., 2018). As a new player, one is offered a "Qualifying Segment" by the system which allows them to get fast bonus-point earnings; thus, instant gratification. Most, if not all, programs award bonus earnings to premium-cabin passengers and their elitestatus members based on tier status. A common bonus for these passengers is to earn an extra 15%–55% of the miles flown on a given flight. Points can be redeemed for air travel, other goods or services, class upgrades and airport lounge access. For the tier system, the game progress model of a FFPs can be determined based on the action of qualifying segments of membership tiers, which defined by the number of successful qualifying segments G and the total number of segments within a year T (365 days). Here, we consider the normalized model that the customer can usually get one segment in one day (Table 11). For the point system, data is collected by considering the flight distance. As game refinement requires the highest level (corresponding to the skillful player) to make the result more objective, only the most senior membership was used as a sample. Since the higher status of the customers, the more miles/points they obtain. However, the points for redeeming free segments differ dramatically from the distance. There are three kinds of free segments considered: short, medium and long. Thus, the impact of a free

segment for the highest membership of Fortune Wings Club and the distance within a year to illustrate game sophistication and game experience. The total points one can earn within a year with considering the 80 segments (XIY-PVG) of the domestic travels with the point bonus are about 170,000. Then, the data can be collected from the official website to check the points required for a free flight7, where the results is given in Table 12. From Table 11, every airline company has almost the same strategy of membership management composed of four tiers, except Sky Pearl Club that excludes the platinum tier. Maintaining or promoting the tier corresponds to overcoming a challenge in a game. The trend of these four FFPs increases the GR value with the tier promotion, implying that the tiers system is offering a fun-game experience. This leads to a winwin scenario: customers improve their loyalty and companies increase their revenues (Zuo, L et al., 2018). One dimension is the tiers system involving the sustainability of the frequent customer, while another is the profitability of points system which indicates the popularity of the gamified service since profit may encourage more customers involvement. Meanwhile, Table 12 shows that the highest GR value is 0.045. It is important to note that the more free segments is redeemed, the less challenge is met. This implies that the points system offers a serious-game experience. The points system concerns about the benefit for customers who may feel serious-game experience (a good balance between customer's capacity and challenge) but related to the popularity. The free ticket is so compelling as everyone.

Table 9. Gr Measures for Hotel Loyalty Program in Shanghai/Tokyo/Paris with Focus on Free Nights: Five Hotel Groups Compared

Hotel Groups	Ave. Price ($)	Ave. Redeem Points	Free Nights	*GR*
IHG	75/208/148	18421//50000/34778	6/6/6	0.033/0.033/0.033
Hilton	125/190/190	31400/55400/55000	3/3/3	0.029/0.029/0.029
Starwood	115/247/335	6900/16000/19769	12/10/10	0.035/0.032/0.032
Marriott	143/208/285	13026/36250/32800	15/7/10	0.052/0.035/0.042
Hyatt	146/336/233	13285/20667/18000	4/6/51	0.033/0.040/0.037

4. GAME REFINEMENT AND THE PERCEIVED NATURE OF MIND

Game has existed since 2600 BC and has been the primary conditions of human culture and cultivated various complex activities of the human society such organization, languages, philosophies, war, and art (Huizinga J., 2014). In the beginning, the game was just for relaxation after a busy work or making a simple decision. With the development of society, the game process becomes more complex and meaningful.

Table 10. Tier Membership Levels Based on Four Frequent-Flyers Programs

Membership Tier	Miles/Segments	Extra Bonus (%)
Eastern Miles		
Silver	40,000/25	15
Gold	80,000/40	30
Platinum	160,000/90	50
Phoenix Mile		
Silver	40,000/25	25
Gold	80,000/40	30
Platinum	160,000/90	50
Fortune Wings Club		
Silver	30,000/20	25
Gold	50,000/40	50
Platinum	100,000/80	55
Sky Pearl Club		
Silver	40,000/20	15
Gold	80,000/40	30

Table 11. Gr Measures for Tiers System from Four Ffps

Membership Tier	GR			
	Eastren Miles	Phoenix Miles	Sky Pearl Club	Fortune Wing Club
Silver	0.014	0.014	0.012	0.012
Gold	0.017	0.017	0.017	0.017
Platinum	0.026	0.026	-	0.024

desires to enjoy a flight without payment as well as highlevel services. Thus, these two gamified services organized systematically is to create a program to maintain customer loyalty.

Table 12. Gr Measures for Points System in Fortune Wings Club

Segment	Point req.	Free flights	Qualifying segment	*GR* *GR*
Short (XIY-PVG)	13	13	80	0.045
Medium (XIY-NRT)	28	6	80	0.031
Long (XIY-CDG)	45	3	80	0.022

req.: point requirement $\times 10^3$

Historically, harnessing the power of play had been attempted to serve the purpose which is beyond entertainment. Game designers are constantly working on stronger AI players to compete against human or other AI champions. Similarly, there are human society constantly searching for ways to effectively disseminate ideas, educators constantly seeking appealing learning process, and companies constantly seeking to engage their customers (Gino, F., 2018). The key factor to human conscience that triggers learning is curiosity, which observable from both entertainment and educational perspectives.

Although a mechanical definition of curiosity is unknown, the perceived curiosity from the learning process is measurable from the development of edutainment game. In most cases, edutainment game design tends to favor either extremes (entertainment or education), but not both. Similarly, online learning games (such as the login system) that typically involved monotonous and repetitive action, tend to prioritize either the feeling of attractiveness (i.e. reward) or experience of engagement (i.e. loyalty program), but not both.

Due to aforementioned situations, the perceived curiosity are modelled in two distinct form that corresponds to the player's state of mind: (a) by the growth rate of learning; and (b) the diminishing rate of engagement. The former is named as the momentum-in-mind while the latter is named as comfort-in-mind. Note that, up to this point, the usage of GR value provides a very different interpretation to game design, which is highly dependent on the context of interest.

A. Momentum-In-Mind

Corresponding to the perceived "curiosity" of the player when playing a game, the momentum-in-mind is defined as the growth rate of mind of the player while moving from one level to another by acquiring a set of information from each level (Agarwal, S et al., 2019). In the context of edutainment, momentum is required to be maintained relatively with the time, because curiosity triggers increases the activity in the brain. This helps us identify the perfect combination of education and entertainment in games. As such, the proposed momentum-inmind (p~) is formulated as (12). Here, the t is the time taken to acquire information to reach a higher level in the game. It can be measured as the difference in the levels or in the unit of time.

$$\vec{p} = (\ln \frac{h}{l}) \cdot \frac{1}{t} \quad (12)$$

Table 13 summarizes the mathematical model of game progress using momentum. If the time is reduced, momentum increases and vice versa. Thus, momentum is inversely proportional to time if the progress (h/l) is kept constant. In the context of the board game, the growth is not continuous and mostly redundant. As such, the momentum-in-mind is obtained by (13). B is the information of the game or game progress which the player learns actively while playing the game and t is the time for the player to acquire that information.

Table 13. Momentum-in-mind

Notation	Game progress model
h	Game information at higher level
l	Game information at lower level
t	Time taken between the levels
$p\sim = (\ln \frac{h}{l}) \cdot \frac{1}{t}$	Momentum ($p\sim$) acquired

$$\vec{p} = \frac{(\ln B)}{t} \quad (13)$$

1) Game play stages: It is supposed that most player in games proceed in the manner of two stages, called the 'skill acquiring' stage and 'competitive' stage. The skill acquiring stage is the stage when the player internalizes the skill required for the game (learning). As such, the competition is usually with oneself. At this stage, the goal is set against oneself and that goal becomes the 'mental' barrier (or 'inertial' level) that requires to gain enough momentum. As such, the momentum is expected to be low which implies high learning experience. Another stage is called the competitive stage where the player starts to compete with other players (and get better at it). Since competing with other player involved some level of skill and chance. The uncertainty would become higher which implies high sense of excitement and enjoyment. Most edutainment games lack this stage where very minimal competition existed. Therefore, the learning growth during this period is very low while the momentum is high.

2) Application to competitive games: Several examples of sport games include Table tennis, Basketball, Soccer, Badminton, and so on, while example of board games are Go, Shogi, Chess, Baghchal, and so on. Based on the previous work by (Panumate, C et al., 2017), the branching factor B and the game length D were taken where the GR value were calculated by using (6) and (9), while the momentum $p\sim$ were calculated by using (13), where D is considered as the length t for calculating the momentum for the aforementioned sports and board games (Table 14). Based on the calculated $p\sim$ and GR values, similar pattern was observed where increase in the GR also increases the $p\sim$, and vice versa. This aligns with current understanding of the game play stages where the considered games only reflected the competitive stage of an entertaining games where little learning had occurred.

Table 14. Sports Games: Game Refinement and Momentum

Game	B	D	$p\sim$	GR
Table tennis (post-2000)	54.86	96.47	0.01802898	0.077
Basketball	36.38	82.01	0.01903259	0.073
Soccer	2.64	22	0.01916382	0.073
Badminton (current)	46.34	79.34	0.02099768	0.086
Tic-tac-toe	9	9	0.10602695	0.333
Western Chess	35	80	0.01930085	0.074
Japanese Chess (Shogi)	80	115	0.01654861	0.078
Go	250	208	0.01152868	0.076
Baghchal	242	26	0.09342471	0.075

3) Application to edutainment games: Educational games are played for educational purposes where the intention of the game may be to acquire a new skill (such as a language in

DUOLINGO and MEMRISE) or to check an already acquired skill (such as SCRABBLE)[2]. Players in the educational games grow actively throughout the game. As such, information at lower level and at higher level are taken as the game information. Although SCRABBLE is considered to be a board game, this study considered it as an educational games since its primary purpose is education. As such, the $p\sim$ value is obtained by (12) in the educational games.

Three educational games were considered in this study. The first one is Duolingo, a language learning platform which has pre-structured course and 'Spanish for English Speakers course' is considered in this study. Memrise is also language learning platform which does not have structured courses where the user can create the course according to their convenience but a pre-structured course is also available. Only the language learning perspective is considered for Memrise. where 'Japanese for English speakers' is used for this study. Lastly, Scrabble is an educational game designed to test one's skills where the English language version is considered. These games were chosen for their popularity and step by step progress method which assisted in the analysis of growth rate.

In spite of the fact that Duolingo has utilized many game components in their stage, the *badges* and *winning streak* are explicitly examined because the critical piece of effective gamification is the substance and learning material itself (Boskic, N., and Hu, S., 2015). Also, the primary reason for players interested in Duolingo involves taking in a second language, while the badges and winning streak are utilized to lift up the player motivation. With respect to the work in (Huynh, D et al., 2016), the growth rate of learning and quantifying entertaining experience utilizes formulation (6). As such, the *GR* and $p\sim$ values for each milestone in the badge and winning streak systems are given in Table 15. According to previous studies (Huynh, D et al., 2016), (Huynh, D., & Iida, H., 2017), the *GR* value implies the significant of the winning streak to users' motivation compared to the badges. The momentum in both badge and winning streak scenarios decreases to eventually become almost equal after certain milestones. This implies that Duolingo is more of an educational but entertaining game as well as better for beginner level of learners but not very attractive to learners of advanced level. While winning streak element of Duolingo successfully maintains uncertainty, it does not solve the problem of falling curiosity.

[2] To maintain the fairness, all the three games are considered as language learning educational game. Since the comparison is not between skill acquisition and testing knowledge, it does not make the difference in the results.
The games are tested on an individual basis and not categorical.

Table 15. Duolingo Badge And Winning Streak: Game Refinement (Gr) And Momentum (P~)

Milestone	**Badge**	**L_k**	$\vec{p}$	**GR**
1	6	21	0.03706	0.1166
2	16	67	0.01797	0.0597
3	29	160	0.0914	0.0337
4	61	317	0.00563	0.0246
Milestone	**Winning Streak**	**L_k**	$\vec{p}$	**GR**
1	2.2	21	0.01631	0.0047
2	6.4	67	0.01203	0.0053
3	21.9	160	0.00838	0.0127
4	47.8	317	0.00530	0.0260

Lk : average number of lessons learned;

In Memrise, users are required to accumulate experience point (XP) to cross a particular level. This mechanism works similar to the milestone technique in the Duolingo game. Similarly, the GR and the p~ are calculated where the XP refers to the required XP accumulation to reach a particular level. As evident from Table XVI, p~ value is building up while the GR value is rapidly declines. From such observation, even though the user's learning growth is maintained for a period of time and increases in another, limited game element makes it difficult to keep the user entertained. In addition, in term of catching up with the course structure, it is better for the user when the learning growth gradually increases. Nevertheless, a sudden jump in p~ in Memrise implies that the learning growth suddenly become too large which become difficult to catch up (i.e. Level 8 to 9 and Level 14 to 15). This explains the reason for the declining GR value since acquiring XP point becomes a burden instead of enjoyment which make the game lose its attractiveness for the user (especially when trying to reach level 13). Thus, having diverse game elements during the game play may enhance the game progress and rejuvenate the curiosity of users.

Finally, Scrabble may be considered as another board game but differ because of its scoring mechanism. As such, the scoring rate, the branching factor, and the game length can be observed. Since those information are fundamental for applying the game progress model, the GR value can be computed utilizing the board game model, as in (9). Then, the momentum (p~ value) are calculated by simulating selfplay of an open source game of Scrabble called Quackle Version 1.0.3. The data includes the average of 100 game plays between various levels of AI players. Based on the results of obtained in Scrabble (Fig. 4), the momentum is

highest when the dictionary size is the highest and the game length is the lowest.

This actually aligned with the findings by (Kananat, S et al., 2016) where that study claimed that Scrabble is most enjoyable

Table 16. Memrise Experience Point (*Xp*): Game Refinement (Gr) And Momentum (*P*~)

Level	X P	L_w	$\vec{p}$	GR
1	500	11	0.69314718	2,033
2	1,000	22	0.69314718	1,437
3	2,000	44	0.69314718	1,016
4	4,000	88	0.69314718	0,719
5	8,000	177	0.69314718	0,505
6	16,000	355	0.69314718	0,356
7	32.000	711	0.69314718	0,252
8	64,000	1422	0.69314718	0,178
9	128,000	2844	0,91629073	0,126
10	320.000	7111	0,91629073	0,080
11	800,000	17777	0,91629073	0,050
12	2,000,000	44444	0,91629073	0,032
13	5,000,000	111111	0,91629073	0,020
14	12,500,000	277777	0,91629073	0,013
15	31,250,000	694444	1,16315081	0,008

XP : experience points; Lw : learned words;

when the dictionary size of the AI player is the highest. In contrast, smaller dictionary size and higher game length results in decrease in the value of momentum which implies that high learning growth (due to high *p*~ value) would occur when experienced players (corresponds to high dictionary size or maximum game information) compete within a short period of time.

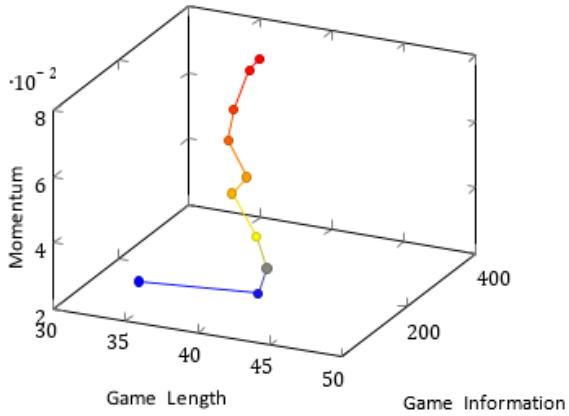

Fig. 4. Momentum in Scrabble. It Can Be Seen That Momentum Is Highest When The Game Length Is Short And Game Information Is Maximum.

B. Comfort-In-Mind

Looking from another perspective, the GR measure provides the whole game playing situation through a single constant value. In other word, both the game element (such as reward) and the total process are constant as well as the attractiveness of the whole process remain the same. However, if the game element along the process changes, how can the measure of attractiveness be determined in any time or step of the process? By focusing on the change of the GR value throughout the game process, its "attractive" tendency can be determined using the third derivatives of (3), resulting in (14). This process gravitates towards increase in attractiveness which represents an addictive-like situation or strong feeling of engagement, namely as the *AD* value given by (15).

$$\begin{aligned} x'''(t) &= \frac{x(t_k)}{(t_k)^n} \cdot n(n-1) \cdot t^{n-2} \\ &= \frac{x(t_k)}{(t_k)^n} \cdot n(n-1)(n-2)t^{n-3} \,|_{t=t_k} \\ &= \frac{x(t_k)}{(t_k)^3} \cdot n(n-1)(n-2) \end{aligned} \tag{14}$$

$$AD = \frac{\sqrt{x(t_k)}}{t_k\sqrt{t_k}} = \frac{\sqrt{G}}{T\sqrt{T}} \tag{15}$$

This value can be perceived as the "force" in the human mind, where the present of "inertia" makes it difficult to persist along the total process. In other word, a timely reward change is an appropriate stimulation to help users continue to overcome the difficult uphill process (potentially caused by boredom). As such, a relation between the bio-mechanical effects and psychological attractiveness can be established. For example, when we take the roller coaster, not only we can feel the gravity, but also we can feel the "attraction" in our mind. As such, the relationship between the change of gravity (phenomenon known as "weightlessness") and the change of attractiveness (in this context, called "addiction") is investigated.

A 'login system' is widely used and relevant in many fields, especially in the domain of online learning games such as

DouDizhu[3], BaiCizhan[4] and Duolingo[11]. A login system is a typical monotonous repetitive action. As such, the system designers are expected to set some rewards to motivate the users to log in more often. From user's point-of-view, such reward in the login system can be regarded as some form of entertainment. However, maintaining engagement in this type of game is not an easy feat, especially with the rise of free-toplay business model of games (Castro, E. G., and Tsuzuki, M. S., 2015) and rising popularity of elearning as an educational medium (Shabihi, N et al.,2016). Some game elements had been adopted to increase motivation and improve retention of the users on such system. Such feats can be achieved by careful attention to the relations between the attractiveness or the loyalty of the users and the game elements (Huotari, K., and Hamari, J., 2012). This is especially true for an online learning system such as login system, where several tiers and different reward rules can be applied. Previous study had provide evidence that "tiers system" is better than the "equal reward" because the process provides smoother decrease of user's attractiveness throughout longer time span (months to years).

Based on this aspects, two popular application named "we are primary school students" and "War poetry" were adopted for this purpose. The first application regulation involves user receiving one reward per day through application login which described by two factors: the number of reward obtained from "continuous login days" and the number of "login days" that corresponds to the *G* and *T*, respectively. The focus is on making more gentle and smooth loss of the user's attractiveness based on the reward rule. As such, 5 different reward rules are defined as in Table 17 which represents an incremental reward system.

Table 17. Five Different Reward Schedules and Rules.

Rule #	Period*	Reward Distribution
1	365 days	1.00
2	365 days/2	0.50, 1.50
3	365 days/3	0.50, 1.00, 1.50
4	365 days/4	0.25, 0.75, 1.25, 1.75
5	365 days/5	0.25, 0.75, 1.00, 1.25, 1.75

*: divided into equal parts;

By applying the five rules in Table 17, the curves of the GR value and AD value are depicted in Fig. 5. Since the login application is a repeated action, losing attractiveness from the users quickly is typical and should be avoided. Fig. 5 (top) shows the change of GR value over time based on the regular reward rule which rapidly declining at the beginning. This implies that the users will lose their attractiveness and feel boring in a short time. However, the decrease of GR values is the least for Rule 5, which indicates a smoother "attractiveness decrease" process. Although Rule 1 to 3 provide better GR value in the beginning, the rapid decrease of the GR value over time would cause the inability of the user to

[3] http://www.auway.net/Games/play/Dou-Dizhu.htm

[4] https://www.baicizhan.com

[11] https://www.duolingo.com/

retain engagement. In addition, the change of AD values over time (see Fig. 5(bottom)) also showed similar tendency of reducing smoothly, especially on Rule 5 which implies gentle losses on users' attractiveness. Imagine the "weightlessness" of the roller coaster, the change of the AD values corresponds to the degree of "attractiveness-less" where it is more acceptable to be experienced by the users little by little. In other words, although "attractiveness-less" can be viewed as a negative experience, it still retains user's sense of enjoyment, which reduces smoothly over a long period of time. As such, "attractiveness-less" that barely noticeable to the users who can make their engagement to be retained longer.

Another example application is the War poetry which adopted similar reward rules and schedules is given in Table 18. This enables the player to obtain login rewards that grows over time, rather than remain constant every day. If the number of rewards and the login days in War poetry is regarded as the G and T, respectively, the changes of the GR and AD values (Fig. 6) can be obtained. The differences of the GR values and AD values, at the beginning and the ending for each login systems is summarized in Table XIX. When the reward system is smoother towards losing user's "attractiveness", the value of $\Delta GR \times \Delta AD$ is lower. This implies that changes in GR and AD values are important factors to retain the engagement of the users. As such, it is important for the system designers to set different reward rules in different time stages. Based on the value of $\Delta GR \times \Delta AD$, both the incremental reward (Rule 4 and Rule 5) and tiers system is the most effective in gently reducing the "attractiveness" and prolonging the engagement of the user.

Although the total reward is a constant, the rate of change of

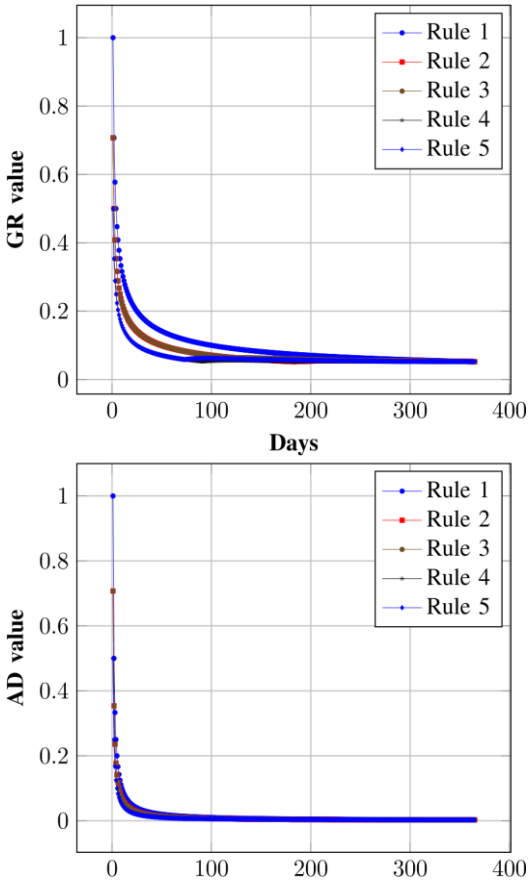

Fig. 5. The Change of Gr and Ad Values over Time: Five Different Reward Rules Compared

Table 18. Different Reward Schedules of "War Poetry" From First to the Seventh Day

Reward rule	War poetry rewards	
	Point system	Tier system
Day 1	1.77	1.00
Day 2	1.77	1.10
Day 3	1.77	1.30
Day 4	1.77	1.50
Day 5	1.77	2.00
Day 6	1.77	2.50
Day 7	1.77	3.00
Total	12.40	12.40

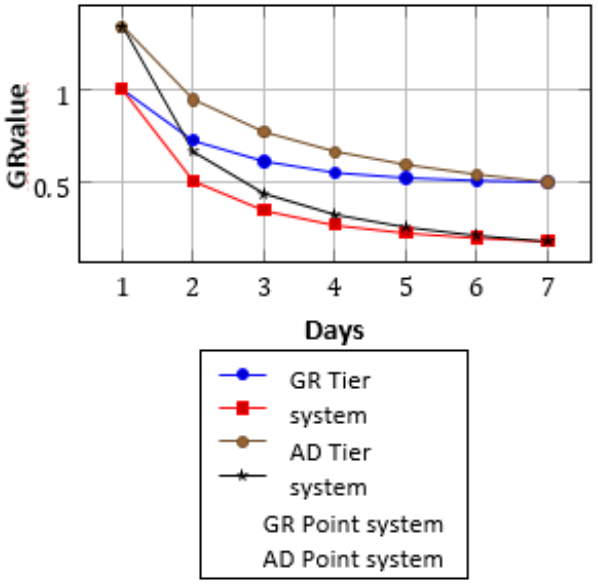

Fig. 6. The Change of Gr and Ad Values over Time: Different Reward Rules of "War Poetry" Compared

Table 19. The analysis of gr value and add value based on login system

Login system	GR_b	GR_e	AD_b	AD_e	$\Delta GR \times \Delta AD$
Rule1	1.0000	0.0523	1.0000	0.0027	0.94514
Rule2	0.7071	0.0523	0.7071	0.0027	0.46124
Rule3	0.7071	0.0523	0.7071	0.0027	0.46124
Rule4	0.5000	0.0523	0.5000	0.0027	0.22264
Rule5	0.5000	0.0523	0.5000	0.0027	0.22264
Point system	1.3310	0.5031	1.3310	0.1901	0.94455
Tiers system	1.0000	0.5031	1.0000	0.1901	0.40244

b: begin; $_e$: end

The GR value had demonstrated some successful cases for the designers to set different reward rules in different stages in two example login applications, "we are primary school student" and "War poetry". Maximizing the user's attractiveness and making them more loyal are achieved by dividing the process to many stages in order to optimize the reward rule (Zuo, L., et al, 2017). Looking from another perspective, the interpretation of the rate of change of the GR values and AD values can be related to the bio-mechanical processes of the roller coaster (Eager, D et al., 2016). ΔGR means the interval of the attractiveness of users in the total process, which implies the range of maximum and minimum "attraction", just like the height of the roller coaster. The AD value is similar with the feeling of "weightlessness" (or related to the force of gravity) where ΔAD implies the interval of the degree of "weightlessness" (changing rate of the GR value). Making both ΔGR and ΔAD smaller would also make the "attractiveness" to decline smoothly. Similarly, the tiers system which corresponds to the value of $\Delta GR \times \Delta AD$, also indicates smooth and progressive reduction of the GR value; thus, corresponds to the acceptability of the user.

5. GENERAL DISCUSSION

Applications of the GR theory have seen much success in quantifying the attractiveness and sophistication of almost all well-known competitive games such sports (Fig. 7), board games (Fig. 8), and video games (Fig. 9). Games that highly depend on luck (shorter game length, high branching factor) are situated in area greater than $GR = 0.08$ while games that highly depend on skill (longer game length, high branching factor) are situated in area lesser than $GR = 0.07$.

These so called "comfortable" zone ($GR \in [0.07,0.08]$) was identified based on a shared patterns of games that found to be enjoyable and attractive to both beginner and advance level players. The zone provides a harmonic balance between the level of challenge and luck imposed on the player when playing the game. For the games that situated area $GR < 0.07$, it is largely dependent on skill that can be made known (or controlled) in order to influence the game outcome (i.e. the precision of hitting on the baseball bat and level of knowledge of a chess player). In contrast, games situated in area $GR > 0.08$ are highly dependent on luck/chance where any small external factors may not be visible (uncontrollable), but nevertheless influence the game outcome (i.e. the

probability of encountering rock for three consecutive time in RoShamBo and change of pace or direction of the shuttle in Badminton).

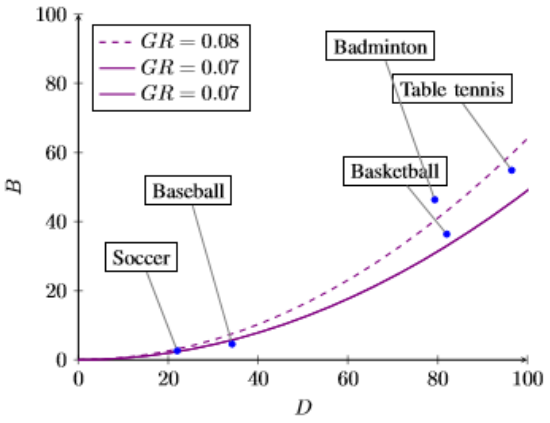

Fig. 7. Comparison of Various Sports Relative To The The Game Refinement Curves of *gr* ∈ [0.07,0.08]. *Gr* = 0.07 and *gr* = 0.08 is the Lower Bound and Upper Bound of Game "Comfortable" Zone, Respectively.

While these "comfortable" zone provide evidence the state of mind of players in the competitive environment, such zone needed to be generalized in much broader context. Based on the application of the GR measure in educational standpoint, a gamified learning experience provides user with better appeal to the overall learning process where technique such as learning milestone had improved the learning experience by making learning session shorter and more engaging (see SectionIII-A). In addition, GR measure also provides indication for users to approach the educational materials in a more sensible manner (i.e. user with motivation). Meanwhile, from the business standpoint, the GR measure provides insights to both the customer and the business owner with respect to their own interests and benefits (see Section III-B). For example, the GR measure for the sales promotion 'discount' provides insights on product popularity and business sustainability, where the zone value balances these two factors so that it becomes beneficial to both customer and the business owner.

In addition, the GR measure of the Starbucks customer loyalty program indicates the need for the customer to spend and the free items the Starbucks willing to give to their loyal customer. Similarly, the GR measure of the gamified services for hotel and airlines loyalty programs also showed that "skillful" customer (becoming loyal customer) will likely enjoy the benefits of their services while the companies systematically improve their revenues. In-depth analysis of the GR measures and its derivatives may also provide a different perspective to the state of mind of users or players. While competition in game may be related to enjoyment and entertaining state-of-mind, little was known to what perceived to happen in our mind when stimulated (such as curiosity during learning) and boredom (such as retention of engagement).

Application of GR measure showed that some of the gamified elements of an edutainment game may entice certain learner curiosity (such as Duolingo entices beginner level learner due to its being an entertaining edutainment game) while impedes learner curiosity when lacks content diversity (see Section IV-A). In addition, skillful or experienced player that compete within a short session would also encourage growth of

learning (i.e. high curiosity). On the other hand, application of GR measure and its derivative (AD value) also provide insights on dealing with boredom. Making a long and repetitive tasks engaging can be difficult, but possible when the sense of enjoyment is incrementally injected in-between tasks (see Section IV-B). Although repetitive tasks can be viewed as negative experience and reduce users engagement, reducing it smoothly and gradually may prolong the sense of engagement as much as possible while avoiding user rejection (or frustration).

By avoiding abrupt and sudden change in the user experience, the bio-mechanical equivalent known as "weightlessness" is imitated from the perspective of the psychological attractiveness, where the force of acceleration (thrills or excitement of accumulating rewards) cancelled out by the inertia (rejection or frustration of repeating the repetitive tasks). Such situation can be perceived as reaching the state of "attractiveness-less", which approximately correlates with "addiction"12. In essence, the findings from the successful application of the GR measure and its derivative have provided evidence on the current paradigm shifts where the state of design for the users or players have shifted from optimizing play experience through various aspect of the game (or their environment) into state of design for the users or players that prioritized comfortable psychological state of mind in various aspects of the game (or their environment). As such, game designer not only needs to design an optimal play experience, but also a comfortable state of mind to provide a holistic approach in game development as well as other related ind ustries; thus, blurring the line between work and play (Iida H., 2018).

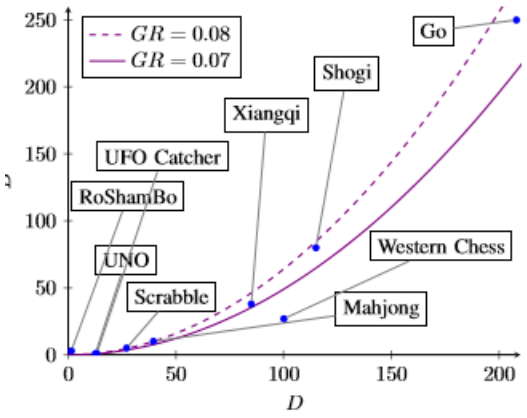

Fig. 8. Comparison of various board games relative to the the game refinement curves of gr ∈ [0.07,0.08]. Gr = 0.07 and gr = 0.08 is the lower bound and upper bound of game "comfortable" zone, respectively.

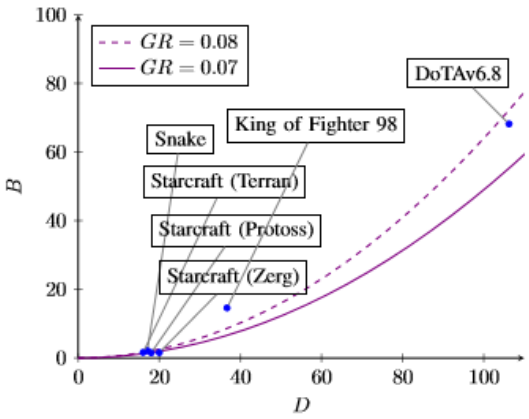

Fig. 9. Comparison of various video games relative to the the game refinement curves of GR ∈ [0.07,0.08]. GR = 0.07 and GR = 0.08 is the lower bound and upper bound of game "comfortable" zone, respectively.

6. CONCLUSION AND FUTURE PROSPECTS

This paper highlights evidences of the occurring paradigm shifts that were observed from the application of the game refinement theory and its derivative in the educational and business perspective, while further explored its utility in understanding and mapping the stimulation and ultimatum of the state of human mind, through the lens of games. Nevertheless, there are still plenty of open problems concerning the current research that requires further exploration.

Since the recent debut of AlphaGo and AlphaZero, fair play becomes an important issue in game (Aung, H. P. P et al., 2019). Mechanically define the term "fairness" from the framework of game refinement theory provide a fascinating prospects in the future. On the other hand, with the recent development of accessible and widely available brain-computer interface technology such as Muse[13], exploring the correlations of the measured brain waves with respect to the game refinement theory, where actual emotional and psychological state of mind can be mapped to distinct labels for better understanding of our brain and how it work, would be an interesting direction for future research. Finally, similar to the work in (Browne, C., 2020).

Which focuses on the physical evolution of games, further exploration from the psychological footprints of game evolution through the framework of the game refinement theory (see preliminary works by (Yicong, W., 2019) can be ventured in the future.

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