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Description	

Where is a line between work and play?

Hiroyuki Iida[a]

Abstract: This paper proposes a notion of force-in-mind by which the boarder between non-game activities such as 'work' and gamified events such as 'play' is identified. It enables us to transform a non-game activity into a gamified one. Force-in-mind is defined as a product of mass-in-mind and acceleration-in-mind like Newton's second law of motion. We conjecture that one would feel gamified experience with a certain degree of emotional impact when force-in-mind becomes equals to or larger than a threshold which is estimated in this study. Moreover, it is likely that a promising link between flow theory and force-in-mind can be found.

Keywords: Work and play, Gamified experience, Non-game activity, Force-in-mind, Flow theory, Game refinement theory

1. Introduction

One of the most popular proverbs in Japan says: "What one likes, one will do well." British historian Arnold J. Toynbee mentioned a related issue by saying "The supreme accomplishment is to blur the line between work and play." This implies that one would be successful in her/his life if she/he is able to blur the line. To our best knowledge, such a line has never been discovered or discussed in a scientific way. So it is a very challenging task to find the line or boarder between work and play.

Dutch historian Johan Huizinga [1] discussed in his well known book "Homo Ludens" the possibility that play is the primary formative element in human culture while giving a definition of play. French Sociologist Roger Caillois [2] followed Huizinga in emphasizing the central role of play in human culture with a focus on diverse subjects such as games, play as well as the sacred. When Huizinga argues that play is essentially not a serious activity, what does the expression "not serious" mean? In this context, a question may arise: "What is the fundamental difference between play and seriousness?"

In this paper, we study the difference between work and play, i.e., just activity and game. A notion of force-in-mind is introduced to measure an emotional impact to feel gamified experience. We then discuss the related works such as flow theory and game refinement theory with a focus on the components of force-in-mind. Moreover, we consider gamified effects in non-game contexts such as education and business. Finally, concluding remarks are given.

2. When just activity becomes game?

Most of tasks as business work are usually scheduled so that they may be completed as scheduled. The work schedule is therefore carefully created based on various information such as the past experience in order to complete on time. This implies that there would be little uncertainty in completing the given task.

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What happen if the task's difficulty increases or the schedule becomes tighter than the original setting? This indicates that there would be some uncertainty in completing the task under such a challenging condition. Thus it is highly expected that a refreshing experience will be made, which cannot be gained in the original setting.

This scenario suggests the possibility that a non-game activity would be turned to a gamified event in which people meet challenges to overcome and therefore feel the sense of accomplishment or satisfaction that is stronger than just activity in non-game context after the task is successfully completed. We present, in Conjecture 1, some aspects of a boarder between just activity and game, which would imply a line between 'work' and 'play'.

Conjecture 1 A task may be gamified if a new condition is given such that one has pressure or feels challenging in completing it. One possible way to gamify is to add a time constraint.

2.1 Information progress model

Let us consider the progress of a task to accomplish within a given time framework. The 'progress' of a task is twofold. One is speed of the task, while the other one is the task's information progress which focuses on the result of the task. The task's information progress presents the degree of certainty of the task's results in time. Having full information of the task's progress, i.e., after its conclusion, the task's progress $x(t)$ will be given as a linear function of time t with $0 \leq t \leq T$ and $0 \leq x(t) \leq x(T)$, as shown in Eq. (1).

$$x(t) = \frac{x(T)}{T}\, t \qquad (1)$$

Here T and $x(T)$ corresponds to the end of the task and the goal to achieve in the task respectively. Eq. (1) indicates that the goal of the task under consideration can be achieved within the time T, meanwhile it may not be so within the shorter time than T.

Under the given time constraint that the task should be completed within the time τ with $0 < \tau < T$ where $x(\tau) = x(T)$, the task's progress $x(t)$ is given as a linear function, as shown in

Eq. (2).

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

However, the task's information progress given by Eq. (2) is unknown during the in-task period since $\tau < T$. The presence of uncertainty during the task, often until the final moments of a task, reasonably renders the task's progress exponential. Hence, a realistic model of information progress of a given task is given by Eq. (3).

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

Here $n \in \mathbb{N}$ stands for a parameter which is given based on the task's progress patterns or hardness of completing the task. Larger n corresponds to more hardness of the goal achievement.

When $1 \leq n$, the first derivative of the task's information progress model $x(t)$ in Eq. (3) or velocity in the sense of dynamics is given in Eq. (4).

$$x'(t) = \frac{x(\tau)}{\tau^n}\, t^{n-1}\, n \tag{4}$$

When $2 \leq n$, the second derivative of the task's information progress or acceleration in the sense of dynamics is obtained by deriving Eq. (3) twice. Solving it at $t = \tau$, we have Eq. (5).

$$x''(\tau) = \frac{x(\tau)}{\tau^n} t^{n-2}\, n(n-1)\,|_{t=\tau} = \frac{x(\tau)}{\tau^2}\, n(n-1) \tag{5}$$

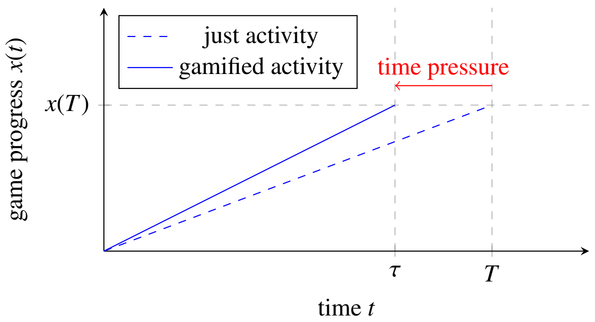

Fig. 1: An illustration: just activity becomes gamified under a time constraint

Remark 1 Under the original condition that a task can be completed within the time T, the given task is not gamified since the task's information progress model, given in Eq. (1), does not have second derivative. Under the new condition as shown in Figure 1, the given task may be gamified since the task's information progress model, given in Eq. (3), has the second derivative or acceleration in the sense of dynamics as shown in Eq. (5).

Definition 1 We call the first and second derivative given in Eq. (4) and Eq. (5) **velocity-in-mind** and **acceleration-in-mind** respectively.

3. Measuring emotional impact as force-in-mind

It is expected to determine a force as a product of mass and acceleration, as an analogy from Newton's second law of motion, i.e., $F = ma$. For this purpose we define both mass-in-mind and force-in-mind.

3.1 Mass-in-mind and force-in-mind

It is assumed that the progress of decision making or sequence of actions on a given task is expressed in the form of its progress tree. For example, it may be a progress tree or game tree. Then we define mass-in-mind based on the concept of progress tree and its reduction rate.

Definition 2 **Mass-in-mind** is defined as an inversion of the reduction rate which is given by the ratio of reduced progress tree over the original tree. **Force-in-mind** is defined as a product of mass-in-mind and acceleration-in-mind.

Let us consider the concept of branching factor of a progress tree. Game tree is a kind of progress tree in the domain of two-person games. For the minimax-based game-tree search, search efficiency like alpha-beta algorithm [3] has been an important issue to develop strong programs. To define mass-in-mind, we focus on the reduction rate of a progress tree.

Definition 3 The **reduction rate of branching factor** (say α) for the minimax-based game tree with B and b ($1 \leq b \leq B$) which stands for the average branching factor and reduced branching factor respectively is defined by Eq. (6).

$$\alpha = \frac{b}{B} \tag{6}$$

Note that the parameter α depends on the deterministic property of a given game. In the deterministic boardgames such as shogi and Go, we see $b \ll B$. The b corresponds to the effective branching factor, which is conventionally defined as average ratio of nodes (or time used) revisited of the current iteration N versus the previous iteration $N-1$. In pure minimax, $b = B$. In alpha-beta algorithm, assuming good move ordering, the branching factor is reduced to about square root of the average branching factor [3,4]. More practically, alpha-beta and other enhancements further reduce the effective branching factor below three, strong programs even near or below two.

3.2 Force-in-mind in boardgames

Sutiono et al. [5] pointed out the gap between boardgame approach with a focus on the average branching factor of a boardgame and game progress approach with a focus on the average scoring points in a scoring sport game. A game progress model $x(t)$ for boardgames was proposed to unify the two different approaches, as described in Eq. (7).

$$x(t) = c\,\frac{B}{D}\, t \tag{7}$$

Further study on the parameter c in Eq. (7) in the framework of game refinement theory was followed by Xiong et al. [6], in which the relation between c and $n(n-1)$ in Eq. (5) was mainly discussed.

In this paper we reconsider the gap between boardgame approach and game progress approach in the framework of force-in-mind. For this purpose, let us consider the move selection process in game playing. A move to play would be selected first in a deterministic way, which is followed by a stochastic way [7]. We show, in Figure 2, a move selection model. For example, in two-person complete-information games such as chess, masters

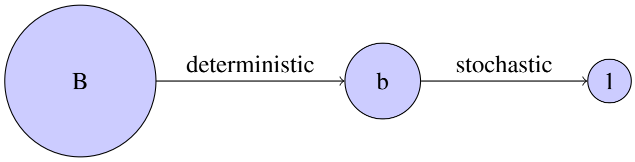

Fig. 2: A model of move selection in games [7]

would consider only a few plausible moves in a position [8], which corresponds to the effective branching factor. In other words, masters are able to reduce the full size of game tree to a much smaller size of game tree.

In the stochastic phase in Figure 2, all candidates would be equally selected. Then we reasonably assume $cB = b$ and obtain a game progress model for boardgames as shown in Eq. (8).

$$x(t) = \frac{b}{D} t \tag{8}$$

However, the game information progress given by Eq. (8) is unknown during the in-game period. Hence the game information progress model is given by Eq. (9).

$$x(t) = b \left(\frac{t}{D}\right)^n \tag{9}$$

The second derivative of the game information progress model is obtained by deriving Eq. (9) twice. Solving it at $t = D$, we have Eq. (10).

$$x''(D) = \frac{b}{D^n} t^{n-2}\, n(n-1) \mid_{t=D} = \frac{b}{D^2}\, n(n-1) \tag{10}$$

Applying Definition 2, force-in-mind F_n is given in Eq. (11).

$$F_n = \alpha^{-1} \cdot x''(D) = \frac{B}{b}\frac{b}{D^2}\, n(n-1) = \frac{B}{D^2}\, n(n-1) \tag{11}$$

On the other hand, a measure of game refinement (say GR) for boardgames [9] is given by Eq. (12).

$$GR = \frac{\sqrt{B}}{D} = \sqrt{\frac{F_n}{n(n-1)}} \tag{12}$$

Remark 2 We see a link between game refinement measure and force-in-mind, i.e., the measure of game refinement is equivalent with force-in-mind if n is fixed.

3.3 Force-in-mind in scoring sports

Let us consider continuous movement games such as scoring sports games. For example, in the score-limit sports such as table tennis and badminton [10], at each turn (scoring chance) its game progress tree has two possibilities: wining a point and losing a point. This implies that the branching factor of the game progress tree is 2. In a competitive game progress, each possibility would happen equally, i.e., $b = B$. No reduction can be made in this progress tree. Then force-in-mind F_n is given by Eq. (13).

$$F_n = \alpha^{-1} \cdot x''(\tau) = \frac{x(\tau)}{\tau^2}\, n(n-1) \tag{13}$$

In the score-limit sports games such as table tennis and badminton, the winner's score and total score per match corresponds to $x(\tau)$ and τ respectively. A measure of game refinement GR for scoring sports games [5, 10] is given by Eq. (14).

$$GR = \frac{\sqrt{x(\tau)}}{\tau} = \sqrt{\frac{F_n}{n(n-1)}} \tag{14}$$

Here we also see a link between game refinement measure and force-in-mind, as described in Remark 2.

3.4 Force-in-mind and game refinement measure

We show, in Table 1, game refinement measures and force-in-mind for boardgames and sports games [5, 10, 11]. Note that it is important to figure out an appropriate progress model in a target domain, which corresponds to τ and $x(\tau)$ in Eq. (3) respectively. Table 1 suggests the possibility of identifying a lower limit of force-in-mind or emotional impact for gamified experience.

Table 1: Measures of game refinement GR and force-in-mind F_n with $n = 2$ for boardgames and sports games

	$x(\tau)$	τ	GR	F_2
Chess	35	80	0.074	0.011
Shogi	80	115	0.078	0.012
Go	250	208	0.076	0.012
Basketball	36.38	82.01	0.073	0.011
Soccer	2.64	22.00	0.073	0.011
Table tennis (pre-2000)	57.87	101.53	0.075	0.011
Table tennis (post-2000)	54.86	96.47	0.077	0.012
Badminton (side-out)	30.07	45.15	0.121	0.030
Badminton (current)	46.34	79.34	0.086	0.015
Baseball (major league)	4.57	34.23	0.062	0.008

Conjecture 2 People feel gamified experience if $F_n \geq F_0$ is satisfied, where F_0 stands for the threshold (lower limit) of force-in-mind for gamified experience and we estimate $F_0 \simeq 0.01$.

The conjecture implies that a task can be gamified even though GR is lower than the sophisticated zone 0.07 to 0.08, if the parameter n becomes larger to meet $F_n \geq F_0$.

4. Possible interpretation of parameter *n*

Eq. (13) is divided into two parts. The term $\frac{x(\tau)}{\tau^2}$ has been used as a measure of game refinement to examine a balance between deterministic and stochastic aspects of the game outcome. It is found that sophisticated games have a similar GR, being located somewhere between 0.07 and 0.08 (see [5, 9]). Another term $n(n-1)$ may correspond to the game progress patterns such as one-side game and seesaw game, or the difficulty of completing the task. The game progress pattern or its difficulty is important with respect to engagement. For example, an investigation has been made in the framework of game information dynamics [12].

Here we consider more general interpretation of parameter n. It is supposed that the parameter n ($2 \leq n \in \mathbb{N}$) in Eq. (3) and Eq. (13) corresponds to the hardness in completing a given task. The hardness will increase as n becomes larger. Such hardness may be estimated by Elo-rating system [13], whereas it is assumed that a stronger opponent in two-team/person games corresponds to more difficulty of completing the task.

In the Elo-rating system [14], winning probability (say p) from the viewpoint of the lower ranking side is given by Eq. (15).

$$p = 1 - \frac{1}{1 + 10^{\frac{-d}{400}}} \tag{15}$$

Where d ($\in \mathbb{R}$) stands for the difference in ratings between two teams/players. When d is positive (negative), p becomes larger (smaller) than 0.5. We show, in Table 2, a possible correspondence between the difference d in Elo-rating and parameter n.

Table 2: The difference d in Elo-rating and possible corresponding parameter n. The winning probability p and expected feeling in game playing are additionally provided.

d	p	n	expected feeling
800	0.99	0	boring
400	0.91	1	little challenging
0	0.5	2	exciting
-400	0.09	3	very challenging
-800	0.01	4	too high challenge

It is expected in other domains such as business and education that the parameter n may be estimated by the population percentage of successfully goal-achieved people over all participants. For example, only few people (say 1%) achieved the very difficult goal, then we would estimate $n = 4$. Further study is needed to establish the way to determine the parameter n for the target domain.

Remark 3 The most exciting setting is given by $n = 2$ in the sense that the outcome is highly uncertain. People would feel gamified experience if GR is a zone value and $n = 2$. Namely, this is a necessary condition to satisfy $F_n \geq F_0$.

4.1 Force-in-mind discovers flow

Table 2 presents several different levels of the 'expected feeling' for each parameter n. For example, $n = 0$ and $n = 4$ may correspond to the situation 'boring' and 'anxiety' in the flow theory [15] respectively. However, we need to consider the difference between fun-games and non-game contexts. We show, in Table 3, a possible correspondence between parameter n and expected feeling in fun-game context and non-game context.

Table 3: A possible correspondence between parameter n and expected feeling in fun-game and non-game context

n	expected feeling (fun-game context)	expected feeling (non-game context)
0	boring	boring
1	little challenging	comfortable
2	exciting	challenging
3	very challenging	very challenging
4	too high challenge	too high challenge

Conjecture 3 $n = 2$ is a reasonable setting in fun-game context or competitive situation like sports, whereas $n = 1$ is a comfortable setting in non-game context with educational purpose.

4.2 Comfortable gamified zone

Eq. (12) and Eq. (14) show a link between force-in-mind and game refinement measure, as shown in Eq. (16).

$$F_n = (GR)^2 \cdot n(n-1) \tag{16}$$

We show, in Figure 3, the relation between game refinement measure GR and parameter n. Further study is needed to identify an upper limit which might relate to addiction or gambling issue.

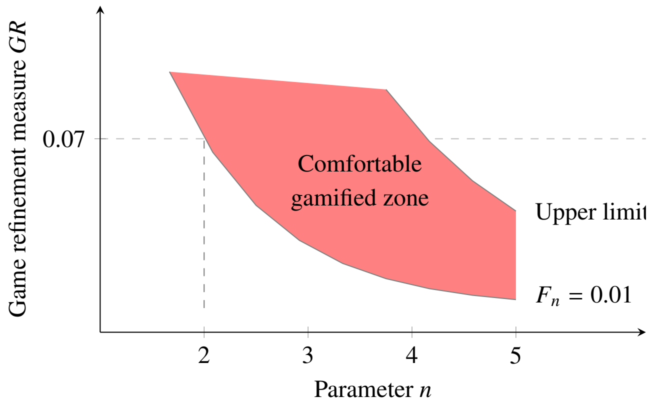

Fig. 3: Comfortable gamified zone estimated by force-in-mind F_n that consists of GR and n

5. Gamified effects in non-game context

The term 'gamification' emerged in the early 2000s, and has been the focus of increased attention since the beginning of the 2010s [16]. The central idea behind gamification is to harness the motivational potential of video games by transferring game design elements to non-game context. Here we analyze gamified effects in non-game contexts such as education and business from the viewpoint of force-in-mind.

5.1 Education domain

Huynh and Iida [17] investigated the effects of the winning streak on users' motivation and engagement in Duolingo, a gamified language learning platform. The winning streak is often used in sport and video games to describe a consecutive number of successful actions and increase players' attention to complete their goal. Similarly, in gamified education system, the winning streak is employed as a game element to boost up motivation of learners. Using a game refinement measure as an assessment tool, enjoyment of two user groups in Duolingo was measured to compare.

The basic framework of game progress model for a language course in Duolingo was figured out by the average number of rewards over the average number of tasks [18]. Additional benefit by the winning streak was considered to modify the original game progress model. The results show that GR is ranged somewhere between 0.02 and 0.03 without winning streak, but improved using winning streak as somewhere between 0.04 and 0.05. Further study [19] confirmed the previous results while comparing the difference between Duolingo and another popular language learning platform MindSnacks in which GR is around 0.03.

To feel gamified experience in the domain of language learning, users should set a noticeably challenging goal which may correspond to the parameter $n = 4$ (see Table 3). Assuming $GR = 0.03$, $F_n = 0.003^2 \times n(n-1)$, so $F_4 = 0.0108$. In other words, only few people would feel gamified experience. This suggests that it would be so hard for most users to feel gamified experience in language learning courses and that it is a very challenging task to design such a really gamified language learning platform.

Suwanviwatana and Iida [20] studied the entertainment experience and learning experience in Scrabble. The game progress model was figured out by the average number of swings over the game length. They consider the possibility of modifying the original fun-game experience into serious-game experience. Scrabble variants, generated using different size of board and dictionary, are analyzed with two measures of game refinement *GR* and learning coefficient *LC*. We show from [20], in Table 4, the summary of the results.

Table 4: Summary of analyzing Scrabble using game refinement measure *GR* and learning coefficient *LC*

Focus	Setting	*GR*	*LC*
Standard	15x15 board 100% dictionary	0.084	98.7323
Entertainment	13x13 board 100% dictionary	0.079	140.9987
Education	15x15 board 4% dictionary	0.240	1333.335
Balance	15x15 board 10% dictionary	0.147	1073.907

The results show that 13x13 Scrabble yields the best entertainment experience and 15x15 (standard) Scrabble with 4% of original dictionary size yields the most effective environment for language learners. Moreover, 15x15 Scrabble with 10% of original dictionary size has a good balance between entertainment and learning experience. It seems that the results support Conjecture 3. The fun-game settings 'standard' and 'entertainment' would meet the gamified experience condition $F_n \geq 0.01$ while assuming $n = 2$. The educational purpose settings 'education' and 'balance' would also satisfy $F_n \geq 0.01$ while assuming $n = 1$.

5.2 Business domain

Zuo et al. [21] studied the benefit of gamified sales promotion with a focus on the hotel loyalty program, which is the essential strategy for the hotel companies in contributing sales volume to its properties and commonly consists of two mechanics: tiers system and points system. They presented a data-driven approach for discovering the two mechanics of the world's largest hotel chains while analyzing the game sophistication level using a game refinement measurement. The results indicate that the range of game refinement value of these two mechanics is meaningful and reasonable in such business domain. The tiers system provides the frequent hotel guests with a fun-game experience, whereas the points system allows them to identify which hotel rewards are more attractive and rewarding.

The game progress model for tiers system was figured out by the number of successful qualifying nights of membership tiers over the total number of days within a year. The game progress model for points system was figured out by the number of free nights over the number of qualifying nights. *GR* for the points system is ranged from 0.029 to 0.043, as shown in Table 5.

Table 5: The ranking of points system based on the average *GR* with considering the location

Rank	Hotel Rewards	*GR*
1	Marriott Rewards	0.043
2	Hyatt Gold Passport	0.037
3	Starwood Preferred Guest	0.033
3	IHG Rewards Club	0.033
5	Hilton Honors	0.029

To feel gamified experience in the points system of hotel royalty program, customers should set a noticeably challenging goal which may correspond to the parameter $n = 4$ (see Table 5). Assuming $GR = 0.029$, $F_n = 0.0029^2 \times n(n-1)$, so $F_4 \simeq 0.01$. This indicates that only few people would feel gamified experience, therefore it would be so hard for most customers to feel gamified experience in the points system only. However, a harmonic combination of the two game elements (pints system and tiers system) successfully increases the possibility to feel gamified experience [21].

6. Concluding remarks

It is expected that force-in-mind (F_n) identifies a boarder between game and non-game activity which may correspond to the issue on play and work [1, 2] while examining if $F_n \geq F_0$, where F_0 denotes a threshold to feel gamified experience with a certain degree of emotional impact. We conjecture in this study $F_0 \simeq 0.01$. There would be many other ways to incorporate game elements (i.e., second derivative or acceleration in the progress model of a given task) into a non-game activity. In this study we mentioned only two aspects: time constraint and difficulty adjustment of goal achievement. Although further study is needed to determine the parameter n, one possible way is to use the merit of Elo-rating system.

It would be useful in game design to maintain an appropriate force-in-mind to attract and motivate people in the learning or growing process, which relates to the flow theory [15]. Game refinement measure (*GR*) that is an element of force-in-mind concerns a harmonic balance between deterministic and stochastic aspects of the result in a given task. Zone value ($GR = 0.07$ to 0.08) would be such a balance that is found in sophisticated games.

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