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Computational Evaluation of Effects of Motivation Reinforcement on Player Retention

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Abstract: We study how virtual incentive mechanisms (such as leaderboards) help motivate players to extend the game playing time. We have designed a multiplayer strategy game, called OilTrader, which is set in a game-theoretic framework of a Minority Game, to verify the effect of motivation reinforcement on the sustainability of game playing process. We have conducted an experiment with 114 players and evaluated their psychological types using the HEXAD player type model. Players were divided into a main experimental group (who used the user interface enhanced with motivation-increasing factors) and a control group (who used a simpler game interface). Results indicate that game players, who have used the motivation-enhancing interface, have had stronger motivation to play the game longer. Using statistical analysis, we have discovered that Free Spirits, Disruptors and Players (according to the HEXAD questionnaire player types) are more motivated by a progress leaderboard rather than an achievement leaderboard.

Keywords: Gamification; reinforcement model; reward system; incentive engineering; motivation; minority game.
Categories: H.5.2, H.5.m, J.4, K.8.0

1 Introduction

Playing can be a powerful motivating factor, facilitating learning and supporting physical and intellectual development of a person [Deci, 00]. In 2012, there were more than one billion computer game players [Kuss, 13] leading to a boom in the online gaming market. There have been many efforts to exploit games for more serious use such as gamification. Gamification is the use of game thinking and game mechanics in non-game contexts [Werbach, 12] in order to engage users and solve serious problems [Zichermann, 11] such as to promote or assess sustainability of complex intelligent physical environments [Silva, 13]. As the use of serious games and gamification techniques continue to grow in popularity, the importance of understanding player retention also increases [Harrison, 14]. Significant effort has been done to understanding what motivates players to enjoy and continue playing games. In game analytics, specifically, regression modelling [Weber, 11], lifetime analysis [Bauckhage 12], kernel archetypal analysis [Sifa, 14], survival analysis

[Allart, 16], and hierarchical multiple regression [Johnson, 16] have been used to model player retention. However, even if specific patterns or relationships between the specific game data and player retention time are found, the results can not be explained without considering the psychological drivers behind human-game interaction [Bauckhage 12].

There is a lack of understanding how different game elements effect different players based on their psychological player types. The paper proposes a method for experimental evaluation of player retention with respect to different psychological player types as defined by the HEXAD model [Tondello, 16] in the context of a motivation reinforcement model. We evaluate the effectiveness of the virtual player incentive mechanism to extend the playing time and perform experimental evaluation in a game-theoretic framework of a Minority Game as an example. We employ statistical methods to validate our findings.

The structure of the remaining parts of the paper is as follows. First, in Section 2 we provide the motivation for using reinforcement models and overview different psychological theories and models of reinforcement as well as factors affecting the player during the game. In Section 3, we introduce with the concept of a Minority Game. In Section 4, we describe the design and development of a game based on a mathematical model of Minority Game as a platform to perform experiments. In Section 5, we evaluate the results. Finally, in Section 6, we summarize the research results and discuss future research possibilities.

2 Factors and models of reinforcement

2.1 Motivation for reinforcement models

Using gamified systems and applications, the engagement, interaction, collaboration, awareness, participation productivity and learning motivation of users can be increased in various domains such as team organization [Kim, 15], project management [Ašeriškis, 14a; Ašeriškis, 14b], e-commerce [He, 04], e-learning [Luo, 15], healthy lifestyles [Berger, 16], tourism applications [Negruşa, 15], etc. Such mechanisms can be used to reinforce player motivation to play as they contribute to initiation, development, and maintenance of gaming behavior [King, 10]. Games can evoke a lot of different affective states, and some of it can be utilized to keep the player involved in the game [Chanel, 08]. The aim of the gamification designer should be to increase and retain the number of game players as well as to prolong game lifetime by maximizing user involvement and satisfaction, while minimizing negative emotional episodes such as caused by frustration, which can cause the player to stop playing the game. Achieving this aim is not a simple task since all players are different: they have different personalities but also different abilities [Chen 07]. Furthermore, the abilities of a player may change during the course of the game, as a novice becomes a mature player and an expert.

Developing motivation enhancement and reinforcement models and methods is important for many areas where active and sustainable participation of agents is key for the success of the entire process, e.g., in digital game-based learning [6, 14], to foster entrepreneurship education [Fonseca, 12], or to facilitate management of software development processes [Herranz, 14].

Many gamified systems encourage user participation using virtual forms of incentive like points, badges, leaderboards [Nah, 15], progress bars, performance graphs or avatars [Sailer, 13]. These incentives translate a player's time and effort investments into a form that is quantifiable, comparable and communicable to his/her peer [Go, 15]. As such, they indicate a player's status and in-game progress, as well as motivate them to continue engaging in gameplay. For example, several of the most popular user-contribution based sites such as StackOverflow, TripAdvisor and Quora, provide some form of recognition to their users for their overall contributions to the site such as "Highest scoring answer that outscored an accepted answer with score of more than 10 by more than 2x" (Populist Badge) (see http://stackoverflow.com/help/badges). Such badges are meaningful incentives for their user performance contributing to the success of an entire community as well. Badges have a social-psychological meaning, and usually have only a symbolic value within a virtual community [Immorlica, 15]. Different players may value winning a badge differently. The value of incentives depends upon the number of incentives already given to the player and other players and tends to decay over time [Easley, 13]. Therefore, badges have a diminishing utility, where the value of each badge decreases over time as the number of players, who earned that badge, increases.

Playing games is not always enjoyable. If the challenges presented in a game repeatedly exceed player's skills, they can cause frustration [Breuer, 15]. In zero-sum games, the success of one competitor leads to the failure of another, which is likely to cause negative emotional reactions. While competition in itself can also be fun and rewarding, the possibility of losing to a competitor introduces the risk of adverse emotional experiences. An unfavourable outcome (i.e., losing) can increase negative emotions such as aggression. Players that get frustrated have a higher chance of quitting the game [Canossa, 11]. Therefore, the game (or gamification) designer should design (or adopt) a player reinforcement model that can help to alleviate player frustration by providing awards and recognizing player effort aiming to sustain long-term users' motivation. On the other hand, if there is a player that is significantly better in playing the game and is constantly (and predictably) winning, it introduces the elements of boredom in the game both for the constant winner as well as to other players and game spectators. As boredom encourages the pursuit of alternative goals outside of the game [Bench, 13], it reduces the number of players staying in the game.

As the emotional impact of the game is mainly based on the concepts of success and failure, the properly constructed reinforcement model must assure and increase positive emotions of players by incentives, which provide immediate recognition of players' success, or keep encouraging players, when they fail, but still show good results. Incentives can be awarded for meeting absolute targets or relative targets. However, if the reinforcement model is connected only to the absolute achievements, the model may work against itself as the less performing players are likely to be disincentivized and may give up and leave the game ('discouragement effect') [Minor, 13]. Special incentives should be made for successful comebacks after failures to reinforce such behaviour rather than game quitting.

To avoid that, the motivation reinforcement model should be carefully designed to fit differences in player skills and promote continuation of the game. If the motivation reinforcement model is properly balanced, it can drive the players to a highly motivating emotional flow-state [Csikszentmihalyi, 90]. The state of the player can change because of the player's progression through the game levels leading to increased complexity of the game and potentially giving rise to anxiety, or because of the increased competence of the player while the game stays at the same level of difficulty, which potentially can lead to boredom. In both cases, the game designer should design the scenario of the game to maintain a player's state of pleasure and involvement, while keeping gradually increasing its difficulty according to the competence and emotions of the player. Extending our knowledge in this area can help researchers to understand the behaviour of gamers better, while game designers can promote serious games better.

Based on Flow Theory [Csikszentmihalyi, 90], Chanel *et al.* [Chanel, 08] have defined three different emotional states: boredom (negative-calm), engagement (positive-excited) and anxiety (negative-excited). Boredom is caused by unchanging environment, or monotonous, predictable or repetitive changes, or lack of novelty, and it can be recognized by lower cognitive load of a player during the game [Sharek, 14].The experience of boredom is negative and aversive, creating a desire to change from the current state and avoid future states of boredom. Enjoyment appears at the boundary between boredom and anxiety, when the challenges are just balanced with the person's capacity to act in a game [Csikszentmihalyi, 90]. Engagement and immersion are defined in terms of cognitive and psychological states such as participation, presence, and arousal [Martey, 14]. Immersion causes the player to focus his/her attention into the game world resulting in lack of awareness of time and of the real world [Nylund, 15]. Immersion can be maintained by keeping proper complexity and interestingness of a game and its results.

To engage individuals, any reinforcement system must provide immediate feedback on player performance [Richter, 15]. However, feedback does not have a direct positive effect on performance [Kluger, 96]. The implementation of feedback (e.g., the level of detail, the timing of feedback) directly influences the results of feedback [Weiser, 15]. Positive feedback (agreement) reinforces the change in the same direction; while negative feedback (disagreement) causes a change in the opposite direction, and homeostatic feedback maintains equilibrium [Spink, 98]. The role of feedback is especially important in social networks and other collaboration-based practices that underline the importance of effective communication in virtual communities. The strength of relationships that bind a member to a community can be influenced by the impact a member can make as well as a feedback that a member can receive from a community. The success of a virtual community relies on the voluntary contribution of valuable intellectual property of individuals to a community without explicit compensation [Roberts, 06]. Even if an individual does not receive any explicit reward for his/her contribution, he/she often wants his/her contribution to make impact or at least be seen. Capturing and understanding feedback received from users also is critical for understanding user motivation and engagement.

According to [Heller, 11] and [Mendoza Gonzalez, 07], in order to be effective, feedback must be 1) persuasive (i.e. influencing future state of community and behaviour of community members), 2) contextual (i.e. include context information by default), and 3) informative (i.e. convey useful information), 4) contributive (i.e. contribute towards benefit of a community as a whole), 5) continual (i.e. to support conversation as narrative of community), 6) expressive (i.e. demonstrate polarity using affective means such as emotions), and 7) effortless (easy to use).

2.2 Summary & our reinforcement model

Players can be grouped into a few types based on their psychological differences and attitudes towards games, and game designers can exploit the specificities of each group to implement the motivation supporting mechanisms throughout the game aiming to keep the player in the game as long as possible [Park 17]. The main tools of keeping the player in the state of flow during the game are various types of rewards. The reward systems are usually multilevel systems, i.e., they are usually based on a hierarchy of different levels to attain [Dubina, 15]. According to Wang *et al.* [Wang, 11], there can be eight forms of reward in games:

1. Score systems such as leaderboards use numbers to mark player performance.
2. Experience point reward systems reflect player effort rather than skill.
3. Virtual item rewards have collecting and social comparison value.
4. Resources are virtual items that can be collected and used to affect gameplay.
5. Achievement systems encourage players to complete specific tasks of a game.
6. Feedback messages are used to create positive emotions and provide instant rewards in response to successful actions.
7. Animations and pictures are used as to provide a sense of fun and mark player achievement.
8. Unlocking mechanisms give players access to game content once some requirements are met.

The goals of the reinforcement systems have been summarized by the Corners of Reward model [James, 13] as intrinsic (achieving own goals), extrinsic (succeeding in leaderboards) and social (competing with other players).

Hereinafter, we propose our own reinforcement model for games with the following elements:

- Winning: reward is provided if the player has won in the previous round of the game;
- Ranking: reward is provided if the player has excelled over his/her competitors over time and has been listed in one of the top positions of the leaderboard of winners;
- Advancement: reward is provided if the player payer overtook a significant number of his/her competitors in the previous round of the game;
- Achievement: reward is provided if the player has achieved the best result in some interesting nomination, e. g., has won over the largest number of his/her competitors;
- Luck: reward is provided on a random basis to some of poor performing players just to increase persistence and total effort of players and incentivize them to keep playing.

These elements provide both static (momentous) and dynamic (continuous) views to the effort and contribution of players in time as well as introduce the element of randomness to allow the certain degree of uncertainty in the system. Each of these elements of reward is supported by a set of the desired characteristics as follows:

1. Visibility: the rewards should be seen for other players to increase competition, gain a social value and increase overall interestingness of a game.
2. Fairness: the reward system is open to all players.
3. Chance: the rewards should be awarded at random intervals to keep interest in the game.
4. Scarcity: reward should not be a common thing in a game.
5. Stability: there are agents awarded during each round.

The proposed model has been developed for single player, turn-based games with infinite teleology according to the multi-dimensional typology of games [Aarseth 03], and targets the needs from beginners to intermediate players. Next, we analyse Minority Game [Ma, 10] as an example of game for which we construct the reinforcement system using the described reinforcement model.

3 Development and Design of the OilTrader Game

3.1 Minority Game

Minority Game (MG) is a well-know game-theoretic model, which is based on the idea that the decision of the majority is always wrong [Ma, 10; Damaševičius, 17]. Minority-like games occur frequently in everyday life, when an action taken by more people becomes less attractive. This occurs, e.g., in the selection of candidates in the university admission system, or when selecting a route in urban traffic systems. MG is also related to congestion games, which can model diverse phenomena such as processor scheduling, routing, and network design [Nudelman, 04]. In these games each agent is allowed to choose a subset from a set of resources, and agents' costs depend on the number of the other agents using the same resources. A congestion problem arises whenever there is a competition for a limited resource and the lack of coordination among users how to exploit it [Bottazzi, 02]. The solution of many problems provided by the MG model is important to the sustainable development of many aspects of the society such as sustainable exploitation of resources, sustainable development of infrastructure and transportation [Ancel, 15], environmental efficiency and sustainable development of financial markets [Tanaka-Yamawaki, 06].

The classical MG is defined as follows [Challet, 97]. The MG is played with an odd number of agents N. Each agent i can choose between two possible actions: to use the resource – represented by 1 – or not to use it – represented by 0. The payoff is +1 if the agent is in the minority and −1 if it is in the majority. To succeed in the game, the players must consider the behavior of other players when taking the decisions.

Consider a population of N agents playing a game G. The game G consists of a number of game rounds g_i. Each agent has a state S assigned to it. An agent is assumed to make repeated choice between finite number of alternatives (or actions, or options) x_i, i = 1, …, N. Each alternative is associated with the result of a game round described by the win function and the reward $r_i > 0$.

The aim is to define a reinforcement system such that the agents would continue playing the game for a longer period of time. We assume that an agent takes the decision to continue playing or to exit the game based on its inner state. For simplicity, we assume that the agent can be in the positive state (engagement) or in the negative state (frustration). If the agent is engaged after the previous round of the game, it takes the decision to continue playing the game. We assume that an agent is in a state of engagement if it is not in the state of frustration, i.e., the states are mutually exclusive. An agent is in a state of frustration if it feels that it is not being rewarded enough for its efforts. Being in the state of frustration increases the chance of leaving the game. OilTrader game developed to model the influence of reinforcement on player decision to continue or leave the game.

3.1 Concept

OilTrader is a market simulation game, which allows to trade shares of oil to money or to buy oil shares. The game serves as an illustrating example of how real world markets would behave if there were no external influences. The interface of the game is presented in Figure 1.

OilTrader is a simulator which allows for users to experience simplified market conditions while trading the digital shares of the fantasy company OilFund. It involves seeing historical game outcomes and trying to predict outcome of the next round. The game consists of rounds, each thereof takes 15 seconds. Each player starts with 500 shares and 500 dollars. In each round, a player makes a decision to sell or buy the OilFund shares, or is not to place any trades in that round. Only a single trade can be done in a single round. The user sees four sections in the game. At the top, he/she sees his/her money and the OilFund shares. At the left column, the user sees trading controls and round timer. Below it, he/she sees trade history data and the impact on his/her money or shares the trade had.

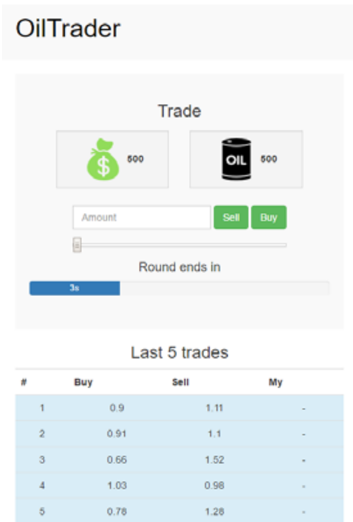


Figure 1: Schematic diagram of the game.

3.2 Game Materials

The physical aspects of the game (Figure 1) are comprised of tokens. Tokens are divided into the following three types:

- Oil tokens: cylindrical markers representing the player's ownership of oil.
- Money tokens: sack-shaped markers representing the player's ownership of money.

3.3 Sequence of the Game

Each player starts by entering the game website. Next, he/she registers and logs in to the game. From the beginning, the player needs to pick action for the current round. He/she is able to sustain, sell or buy oil. The player picks an action and enters how many oil shares he/she wants to sell or how much money he/she is willing to spend to buy oil shares. After his/her decision he/she waits for the round to end. Each round takes 15 seconds. The trade is evaluated determining the seller to buyer ratio. Using this ratio, the player resources are redistributed based on the Minority Game logic. Each round outcome randomized, so each player is affected fairly. Finally, the player can decide to leave the game or continue to play the next round. Figure 2 presents the steps of the game as follows:

1. Pick an action;
2. See the results of the game round;
3. Take a decision to play or not to play the next round.

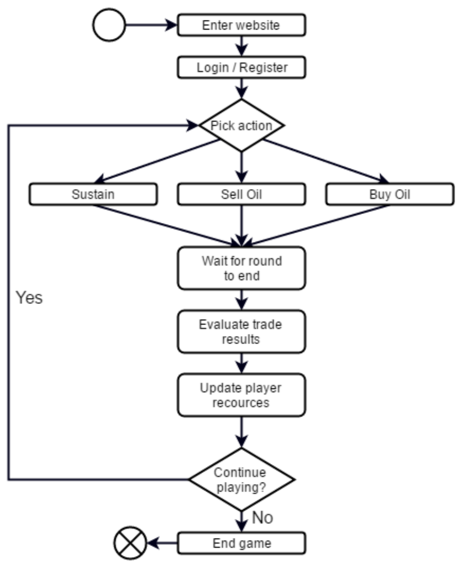
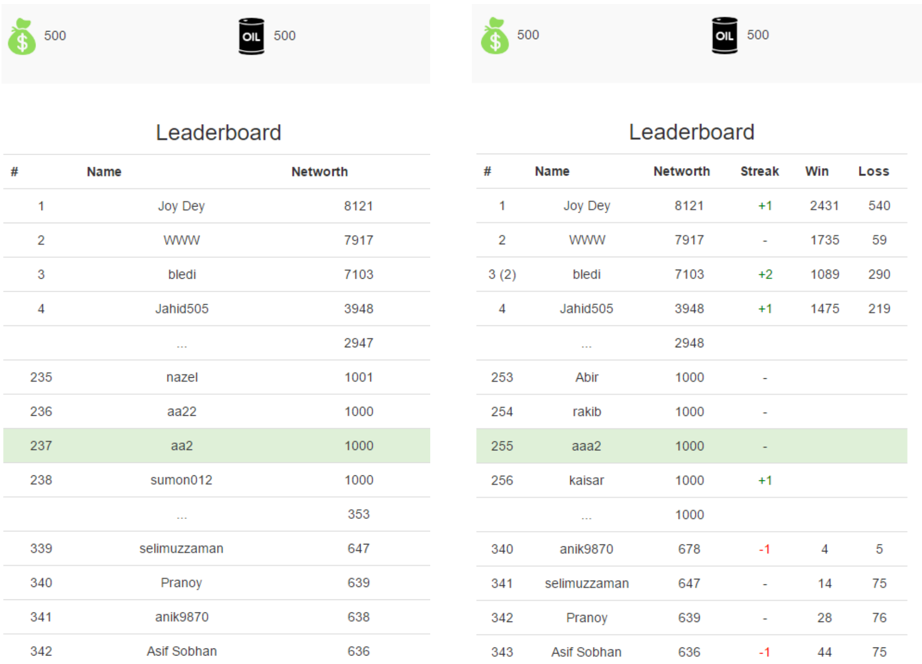


Figure 2: Flow diagram for game steps.

3.4 Motivation reinforcement mechanism (incentives)

For simplification, we assume that a player can only be affected by the elements of the game's user interface which he/she can see. Our hypothesis for this experiment is that it is possible to evaluate the influence of the reward mechanism (visually represented as a leaderboard table) on the duration of game playing depending on the different psychological types of player.

We have divided all users randomly into two groups: the main (experiment) group and the control group. The game's user interface for the control group has the leaderboard which represents player achievement, and shows player position, net worth (shares + money) and win or lose state in the latest round of the game. The game's user interface for the experiment group has additional three metrics (streak, biggest win, and biggest loss), which represent player progress, and are aimed to incentivize the internal player reward (see Figure 3).



#	Name	Networth
1	Joy Dey	8121
2	WWW	7917
3	bledi	7103
4	Jahid505	3948
	...	2947
235	nazel	1001
236	aa22	1000
237	aa2	1000
238	sumon012	1000
	...	353
339	selimuzzaman	647
340	Pranoy	639
341	anik9870	638
342	Asif Sobhan	636

#	Name	Networth	Streak	Win	Loss
1	Joy Dey	8121	+1	2431	540
2	WWW	7917	-	1735	59
3 (2)	bledi	7103	+2	1089	290
4	Jahid505	3948	+1	1475	219
	...	2948			
253	Abir	1000	-		
254	rakib	1000	-		
255	aaa2	1000	-		
256	kaisar	1000	+1		
	...	1000			
340	anik9870	678	-1	4	5
341	selimuzzaman	647	-	14	75
342	Pranoy	639	-	28	76
343	Asif Sobhan	636	-1	44	75

(a) **(b)**

*Figure 3: OilTrader leaderboard of **(a)** control group, and **(b)** experiment group (with streak, win and loss incentives)*

4 Description of the Experiment and Validation of the Game

4.1 Purpose of the Game Experiment

This experiment has three main objectives:

- to validate the playing motivation of experimental subjects using the proposed motivation model and the HEXAD player typology [Tondello, 16] & questionnaire [Diamond, 15] ;
- to identify any difference in the effectiveness of motivation-enhanced game interface between the experimental group (which was presented with used a motivation-enhancing leaderboard) and the control group (with used a basic leaderboard);
- to discuss the relationship between the HEXAD player types and player motivation to play the game longer.

4.2 Experimental Subjects

The experiment was conducted in June 2016. Using crowdsourced workers from microworkers.com (a web-based crowdsourcing platform to access the crowd which enables the employers to submit individually designed tasks [Hirth, 11]), we have setup a task to play the game and afterwards to fill in the player type questionnaire. We have randomly assigned players to control and experiment groups once they created an account. In total, we have enrolled 114 players who played the game. Participants in the study where mostly male (88.6%). 70.2% of participants were between 20-30 years old. 17.5% of participants were 30+ years old. 12.3% were younger than 20 years old. Majority of participants play games up to 3 hours a day (67.5%) and 23.7% play above 3 hours. Only 8.8 percent of participants do not play computer games regularly. 69.2% of participants enjoyed the activity versus 31.8%, which said they did the task only for money.

All participants have received introductory information about the task they have been asked to perform (to play a game). Then all players could start playing the game and exit from it at any time they wanted. After finishing the game, the participants were asked to complete the HEXAD questionnaire [Diamond, 15]. The completion of the questionnaire was not mandatory, but only the results of players who have completed the questionnaire voluntarily, have been analysed in this study (99 players, 86.8%).

4.3 Research Tool

To assess the motivation reinforcing aspects of the game interface, we use the HEXAD player type classification [Diamond, 15], which has 6 player types:

- *Socializers* are motivated by being closer to other people. They seek to create new social connections and relationships.
- *Free spirits* are motivated by autonomy and self-expression. They like to explore.
- *Achievers* are motivated by mastery and overcoming game challenges. They continuously need to improve themselves.

- *Philanthropists* are driven by altruism helping others without any reward for themselves.
- *Players* are motivated by extrinsic rewards. They are playing the game only if they expect to be rewarded.
- *Disruptors* are motivated by changes. They are willing to ‘disrupt’ the game rather by playing by its rules.

First, we assign a player type to each player and then we evaluate the length of gameplay for each player type. To assess player type, we employ the HEXAD questionnaire (see Table 1) [74; 75].

Player type	No.	Items
Achiever	Q6	I am very ambitious.
	Q15	I like defeating obstacles.
	Q20	It is important to me to always carry out my tasks completely.
	Q24	It is difficult for me to let go of a problem before I have found a solution.
	Q27	I like mastering difficult tasks.
Disruptor	Q5	I like to provoke.
	Q11	I like to question the status quo.
	Q18	I see myself as a rebel.
	Q22	I dislike following rules.
	Q29	I like to take changing things into my own hands.
Free Spirit	Q3	It is important to me to follow my own path.
	Q9	I often let my curiosity guide me.
	Q14	I like to try new things.
	Q21	I prefer setting my own goals.
	Q26	Being independent is important to me.
Philanthropist	Q2	It makes me happy if I am able to help others.
	Q10	I feel good taking on the role of a mentor.
	Q17	I like helping others to orient themselves in new situations.
	Q23	I like sharing my knowledge.
	Q28	The well-being of others is important to me.
Player	Q7	I like competitions where a prize can be won.
	Q13	Rewards are a great way to motivate me.
	Q16	I look out for my own interests.
	Q25	Return of investment is important to me.
	Q30	If the reward is sufficient I will put in the effort.
Socializer	Q1	Interacting with others is important to me.
	Q4	I like being part of a team.
	Q8	It is important to me to feel like I am part of a community.
	Q12	It is more fun to be with others than by myself.
	Q19	I enjoy group activities.

Table 1: The HeXAD Questionnaire [Tondello, 16]

5 Results

In this experiment our hypothesis is that different player types are impacted differently by different reinforcement models of the OilTrader game. The motivation to keep playing is evaluated as the number of game rounds actually played by the player. When analysing the answers obtained from the questionnaire, we have noticed that some players have filled it randomly or in such way we could not classify the player into any group. Following the recommendations presented in [Hossfeld, 14], we perform the two-stage statistical analysis. The first stage tests the reliability of the players. The intention of this stage is to create a pseudo-reliable group of players, who are analyzed in the second stage. The unreliable player ratings are determined based on the results obtained from the HEXAD questionnaire. Only the results of the reliable players are used in further analysis. This approach is also known as pilot task and main task [Soleymani, 10]. The number of player disqualified in the pilot stage can be as high as 60% [Soleymani, 10].

We have evaluated the reliability of players' answers as follows. First, we assume what if some players belong to the same player types, their answers to questions defining this particular player type would be similar, while the answers to other questions would be scattered. Based on this assumption, we have filtered out players (10%, by rank), for which there was the smallest difference between standard deviations of answers to questions representing different player types. The second assumption we made is that a player would choose the highest score for the answers which correspond to his/her player type, while for all other answers the scores would be scattered. In this case, we have removed players (10%, by rank), for whom there was the largest difference between the mean score of all answers and the largest mean score of answers for questions representing different player types.

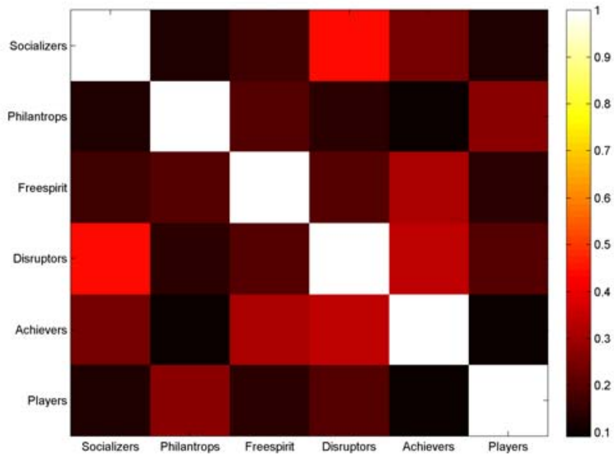


Figure 4: Distribution of players between player types

We have assigned player types to the remaining players using the following rule: a player is assigned to a player group if the sum of answer scores to the player type questions exceeds the median of the sum of the answer scores for that player group by its Median Absolute Deviation (MAD) as follows:

$$\sum_{Q_t \in Q} S(Q_t) > median\left(\sum_{Q_t \in Q} S(Q_t)\right) + mad\left(\sum_{Q_t \in Q} S(Q_i)\right) \quad (1)$$

here Q_t – a subset of questions for a player type t, and S – score.

We have evaluated similarity of the obtained player groups using the Jaccard similarity metric as follows:

$$J(G_1, G_2) = \frac{|G_1 \cap G_2|}{|G_1 \cup G_2|} \quad (2)$$

here G_1 and G_2 are player type groups.

The results are presented in Figure 4. The number of unreliable and unclassified players removed in the pilot stage of statistical analysis was 34 out of 99 (34.3%). We have allowed the same player to be assigned to different player types. Mean overlap between player groups was 20.5%. In best case, there was only 9.1% similarity (between Achievers and Philantrops), and in worst case there was ~44.4% similarity between two different player type groups (Disruptors and Socializers).

To evaluate the duration of gameplay, we have selected median as a statistical measure that is more robust to outliers than arithmetic mean. The median results show that the players of the experiment group have played 12.2 ± 2.9 rounds, while the players of the control group have played 10.3 ± 2.4 rounds (Figure 5). The paired-sample t-test rejected the hypothesis that both sets of data have equal means ($p = 10^{-48}$).

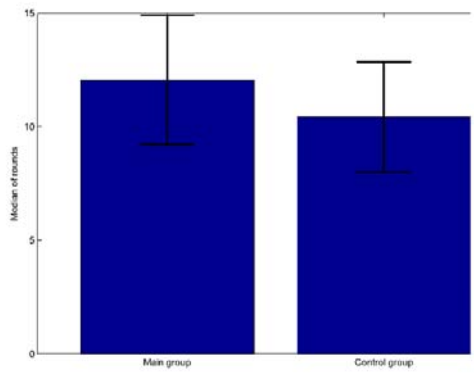


Figure 5: Median gameplay duration for main group and control group

The results of the permutation test (Figure 6) shows that main group players have higher probability ($p = 0.671 \pm 0.008$) of playing longer than control group players ($p = 0.329 \pm 0.008$).

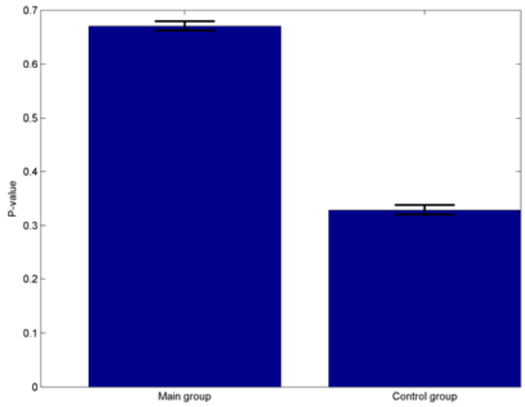


Figure 6: Probability of playing longer (permutation test)

We have evaluated the limits in which the experiment group has outperformed the control group based on the assumption that the gameplay results (medians of rounds played) follow the Weilbull probability distribution, which is often used to model time-to-failure in reliability engineering. Note that we can interpret the decision of a player to exit the game as game failure.

We can see that the number of players leaving at early stage of the games was larger for the control group than for the main group. We have used two methods to evaluate the limits when there were a larger number of players from the main group exiting the game (see Figure 7).

First, using the bootstrapping method (bootstrap data sample is 1000) we have calculated standard deviations for each round of the game and selected the limits where confidence intervals do not overlap. The results show that the players from the main group were more likely to exit the game starting from the 17th round up to the 25th round.

Second, we have used the Students t-test and determined the limits where the test rejected the hypothesis that both datasets have the same mean. The results show that the players from the main group were more likely to exit the game starting from the 7th round up to the 44th round.

We also have identified answers to which questions of HEXAD questionnaire have indicated the most important statistical differences between the main and the control groups in terms of median of played game rounds (see Figure 8 & Table 1).

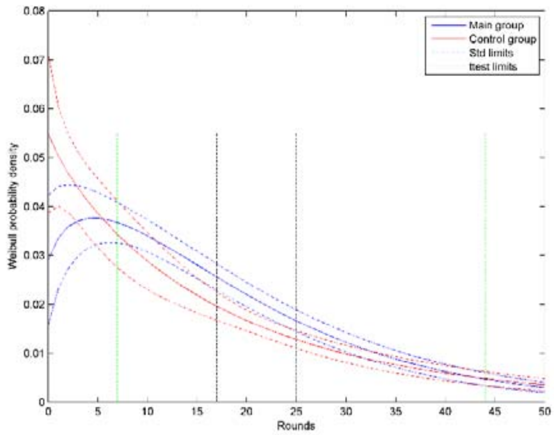


Figure 7: Duration of gameplay (in rounds)

For identification of statistical importance of these questions we have applied the bootstrapping method and Student's paired t-test. The results show that the most significant ($p < 0.05$) questions focus on competitiveness (Q7, $p = 0.003$), curiosity (Q9, $p = 0.003$), novelty (Q14, $p = 0.004$), selfishness (Q16, $p = 10^{-33}$; Q25, $p = 10^{-44}$; Q30, $p = 0.02$), autonomy (Q18, $p = 10^{-94}$; Q22, $p = 10^{-88}$), self-efficacy (Q20, $p = 10^{-25}$), mastery (Q27, $p = 10^{-79}$), empathy (Q28, $p = 10^{-52}$). All these factors have had a positive effect on the duration of gameplay. These results are consistent with the claims of the self-determination theory [Calvert, 76], which emphasizes the role of autonomy and competence in game play motivation.

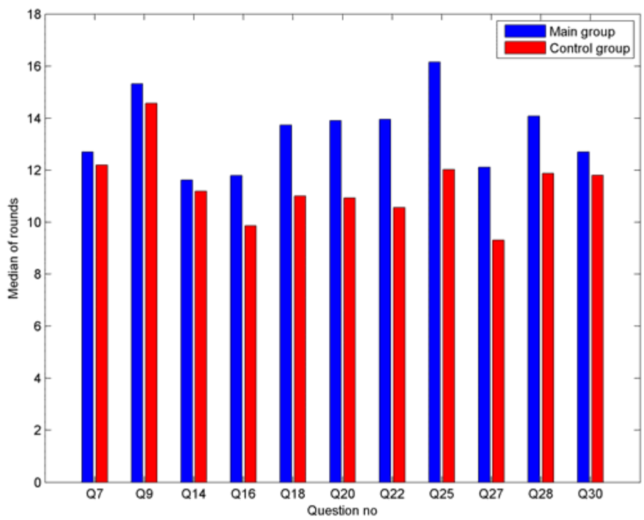


Figure 8: Analysis of questions from HeXAD questionnaire

The duration of gameplay (median number of game rounds play) for different player types is presented in Figure 9. The game interface modified with additional incentives resulted in the longer gameplay for Freespirits, Disruptors and Players, while it was not effective for Socializers, Philantrops, and Achievers.

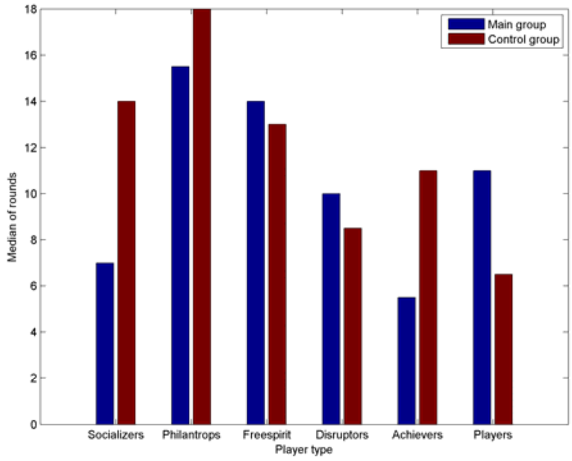


Figure 9: Duration of gameplay for each player type

In Figure 10, we can see the results of a permutation test which shows the probability that main group will have better result (longer gameplay) than the control group by player type. Most significant effects were observed for Players ($p = 0.6906 \pm 0.008$), Freespirits ($p = 0.6267 \pm 0.008$), and Disruptors ($p = 0.5688 \pm 0.008$).

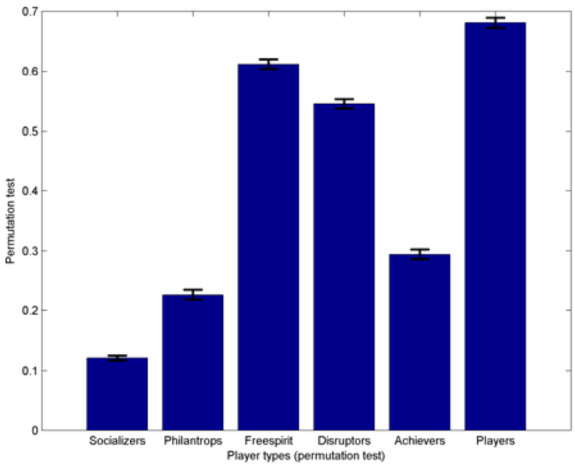


Figure 10: Results of permutation test for different player types

6 Discussion of Results & Conclusions

Efficient and effective satisfaction of human needs is a key to success in many areas of activity. Gamification has been proposed as one of solutions aiming at increasing human motivation in various areas. However, how to design and implement gamification is not always clear as there are many tools and mechanisms available for promoting motivation (such as points, badges, leaderboards), but their effectiveness with regards to different psychological types of players has not been studied before.

We evaluate the effectiveness of an enhanced progress leaderboard with respect to standard leaderboard for different game player types using a simple game based on the game-theoretic framework of Minority Game set in the context of market trading. The results of an experiment show that there is a statistically significant difference between different types of players in accepting the motivation-enhancing mechanisms of gamification. The analyzed user interface solution (progress leaderboard) has been effective in prolonging the time of gameplay for several types of players, i.e., FreeSpirits, Disruptors and Players (according to the HEXAD typology [Tondello, 16]), whereas for Socializers, Philantrops and Achievers the motivation enhancing effect has not been achieved. In our case, Players are known to be motivated by rewards, so presenting them more different kinds of rewards through the enhanced leaderboard has allowed to keep them more interested in the game. FreeSpirits want to explore the game and find different and new ways to gain reward. Disruptors, on the other hand, are interested in breaking the system, so they keep playing for longer just to observe the other players failing. The unexpected result was that Achievers, who are motivated by challenge and mastery, have been found to be not interested in the introduced motivational incentives. Perhaps, the game itself was too simplistic for them to keep them playing for longer, as it does not allow for adjustment of gameplay complexity on a scale that would be required for an advanced or highly motivated player such as an Achiever.

The achieved results can be explained by the inherent psychological differences of attitude towards playing: some types of players play because they like to compete with other players, therefore different leaderboard-based solutions presenting different views on many aspects of competition is perfect for them, whereas other types of player play because of an opportunity to socialize without the need for compete, or just because there are fully immersed and enjoy of the process of gameplay itself without any regard for scores, or only for their own personal scores without the need for comparing it with other players' results.

We also have found that the HEXAD player questionnaire [Tondello, 16] method for determining psychological player types lacks protection from people entering random answers. Following the recommendations presented in [Hossfeld, 14], we have applied the two-stage statistical analysis to filter out unreliable and unclassified players and to minimize the risk of error. These results underscore the need for game & gamification designers to perform surveys and in-field studies of the user interface solutions to evaluate their effectiveness. These results also set the limits of gamification as for some types of players motivation-based gamification mechanisms are not likely to be working due to their psychological attitude towards game playing.

The proposed framework is limited to single player, turn-based games with infinite teleology [Aarseth 03], and does not apply for other types of games such as casual games or real time strategy games. Nethertheless, the elements of the model could be used to develop a motivation reinforcement model for other types of games. Additional research is needed expand the same model to other games to identify if game context to results discussed. Also, a separate result is the need for researchers to continue their work on analyzing different psychological types of players as the result of an experiment performed here show that it is difficult to clearly assign player types to real subject, as the qualities of different psychological types may be mixed in the same person. Rather than defining crisp player types, the fuzzy-like approach to player typology is needed. These conclusions may spur the development of novel player classification taxonomies and player motivation enhancing gamification mechanisms in the future.

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