

CELLS OF WAR: A Serious Game for Familiarizing Players with the Immune System

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Abstract

Background. Health constitutes a major field in serious games because of the wide range of applications and the significant contribution to humans and society. The spectrum of games for health meets the needs for education, training, treatment, rehabilitation, research, well-being, prevention, motivation and others.

Aim. *Cells of War* is a serious card game, aiming to familiarize the players with the complex functionalities of the **immune system**, inform on diseases coming from viruses, bacteria, parasites or fungi and explain how some daily habits may affect health.

Method. This article analyzes all the design steps followed in order to integrate the learning content into the game mechanics and game-play. The offline **card game** was developed in the game engine Unity, making it possible to build executables for Windows, Linux and Mac OS X and distribute them to the users for the first pilot evaluation. The results of the **pilot evaluation** are presented along with useful feedback for the game.

Results. *Cells of War* was evaluated by a wide range of people on different age groups, interests, gaming background, knowledge background and among them a few

health specialists and educators. Overall the game achieved to transfer some knowledge, while the feedback will contribute to the improvement of the game.

Conclusions. The pilot evaluation of *Cells of War* showed that the game is fun, well-designed and achieves to educate the players, although the participants suggested a few issues for improvement. *Cells of War* has to be used and evaluated by students and teachers in order to assess the game as an instructional tool in schools and evaluate its impact on learning the functionalities of the immune system.

Keywords

serious games, health, immune system, diseases, Unity, card game, evaluation

Basic Data

Instructional Objectives

- Familiarize players with the functionalities of the immune system.
- Educate players about diseases and threats to public health.
- Educate players about vaccines and medication.
- Comprehend how both defense and attack function, in order to be able to know how to take precautionary measures, boost the immune system and handle symptoms on time.
- Motivate players to acquire healthy habits and pay more attention to health issues and well-being.

Game Objectives

- Counter a variety of diseases by setting up an immune response using white blood cells, anatomical barriers, medication and other options.
- Acquire beneficial habits and discard harmful ones.
- Acquire immunological memory for a variety of diseases, in order to counter them faster the next time.
- Reach level 50 by defeating pathogens and adopting beneficial habits, before losing all 50 points of life.
- Acquire more knowledge about each card, by reading the extra information provided.

Debriefing Format

Debriefing is important for educational games as it tracks the learning outcome on players, contributes at the improvement of the game, as well as enhances the learning experience (Lennon, 2010). Currently, *Cells of War* does not implement any means for debriefing. However, a future debriefing in-game mechanism could be designed and integrated. In terms of education, the only option for educators is to create questionnaires on the context of the game or debrief the game orally.

Game Genre and Target Audience

Cells of War is a single player, offline, card game with simple mechanics and limited requirements on gaming skills. Thus the game is accessible by a wide range of age

groups interested in health issues. In addition, the game could be used as an educational tool by teachers at schools in order to assist students in understanding how their body functions, motivate them to acquire beneficial habits, pay more attention to health issues and promote active learning.

Preparation and Set-Up Time

The player needs to download the executable and run it locally either on Windows, Linux or Mac OS X.

Playing Time

The nature of the game allows smaller duration for completing a playthrough and higher replayability. As a result the total playing time depends on four factors:

- How many times the player is willing to play the game.
- Whether the random generated effects of the game are in favor of the player leading to shorter sessions.
- Whether the player spends time on reading the extra information provided in the cards.
- As the player gets more familiarized with the cards and the game rules, sessions might last less.

Introduction

According to contemporary research, video games experience amazing growth, numbering 2 billion players worldwide (Newzoo 2017), while the average age for gamers is 35 years (esa 2017), suggesting that video games attract all age groups. However, what is that magic element that makes video games so popular in our society? Przybylski et al. (2010) suggest that video games happen to satisfy most of humans' basic psychological needs: competence, autonomy, relatedness. Sherry et al. (2006) report that gamers play video games in order to experience one or more of the following: arousal, challenge, competition, diversion, fantasy, social interaction. Finally, Prensky (2001) demonstrates twelve elements that make video games the most engaging hobby: They are a form of fun and play, they are interactive and adaptive, they have rules, goals, outcomes, win states, interaction, conflict, challenge and opposition, problem solving, representation and story. As a result, they can trigger a wide range of emotions such as enjoyment and pleasure, involvement, motivation, learning, ego gratification, adrenaline, creativity, sociability and others.

All these native characteristics of video games make them a really appropriate tool to educate, motivate, train, inform, inspire and achieve a greater purpose in general. The so called serious games are designed to entertain the player, while they try to accomplish a specific objective.

Serious games are applied in many fields of society, including military, government, humanitarian, advertising, scientific, culture, corporate and of course education and healthcare. Each one of these fields extends in more subcategories. In healthcare more specifically, the range of applications includes games for training, prevention, education, rehabilitation, research, motivation and more.

Cells of War is a serious game on health, targeting all kind of audiences. The learning material of the game consists of the mechanisms of the immune response, some diseases that threaten the health and a few habits that affect the well-being. The game's original purpose is to educate the players about general health issues and through that, to motivate them adopt a healthy way of living and pay more attention to their health.

Considering relevant work, Su et al. (2014) developed a card game by improving features on Steinman and Blastos' card game (2002). The game is played by two players and consists of three types of cards (immunity, diseases and effect) and a life bar. The players at the beginning of the round, place their cards upside down either upright for direct attack or sideways for counterattack. When both sides finish placing their cards, they turn over the upright cards and each turn they decide if they will attack or defend themselves. The evaluation showed that students were positive, motivated and interested in the game, while it improved their knowledge on the immune system.

Kelly et al. (2007) developed a 3D first person shooter game around the functionalities of the immune system. Many specialists were involved in the design and development process and the integration and visualization of the content seems to be accurate.

HopeLab developed the third-person shooter game *Re-Mission* and *Re-Mission2* in order to support children that fight with cancer and encourage their treatment adherence. The player fights against cancer with multiple weapons and powers based on real strategies like chemotherapy, antibiotics and body's natural defenses. Kato et al. (2008) and Cole et al. (2012) studied the effects of the game and concluded that playing *Re-Mission* led to more consistent treatment adherence, faster rate of increase in cancer knowledge, and faster rate of increase in self-efficacy in young cancer patients.

Finally, the Nobel Foundation developed the *Immune System Defender* that evolves in two phases. In the first phase the player has to exterminate bacteria by moving phagocytes using the mouse. At the second phase of the game the player handles more phagocytes, and after a sufficient number of bacteria is eliminated, he/she has to alert the rest of the system by moving around appropriate cells. When this process completes the player has to answer some questions relevant to the game. The debriefing process for the game (Lennon, 2010) proved that the player learned about the subject by reading the information before the game and not by playing it, while the game was boring, easy and repetitive.

The immune system is a subject that can be successfully integrated into various game genres, such as shooter games or card games. The two aforementioned shooter games are representative examples of games where the player has an active role on the action that takes place. They also require some soft gaming skills compared to a card game. Their purpose and target audience are more specific and they succeed a different gaming and learning experience to the player.

Despite the fact that *Cells Of War* is also a card game, the game-play, the rules and most of the content are varied from the card game designed by Su et al. (2014). *Cells of War* follows a more spherical approach, attempting to visualize the way that the immune system functions in three different levels and how they interact. All the cards have an in-game effect inspired by their scientific description and apart from cells and diseases there are also habits, medication and actions that can also affect health. The game aims to educate players on how their immune system works, help them acquire a deeper understanding of diseases and motivate them on adopting a healthy lifestyle. The motivation for designing and implementing *Cells of War*, besides the different approach that was adopted for transferring the indented knowledge, was the lack of a game on the immune system in Greek. Since, the terminology in this field is rather specialized it would be difficult for students to understand the content of the game if it was not presented in their mother tongue. Currently, *Cells of War* is bilingual (English, Greek) but it can be easily translated in other languages.

In order to design *Cells of War* various theories and serious games design frameworks were studied. The ones that affected more the design of the game are the Conceptual Framework by Yusoff et al. (2009) and the Design, Play, Experience (DPE) Framework by Winn (2009). Specifically, the iterative design process of the DPE Framework was adopted. Based on the DPE Framework several iterations of designing, prototyping and play testing were carried out, exploiting the experience (our own and that of other volunteer player-testers) for refining the game. The design phase, as will become clear in the analysis of the game, was heavily guided by the various features of the Conceptual Framework (Yusoff et al., 2009) and their interrelations: capabilities, instructional content, intended learning outcomes, game attributes, game mechanics, game genre, game achievement, learning activity, and reflection.

The rest of the article is organized as follows. In the next section, the design flow and the way that the learning material was integrated into the game mechanics are presented. This is followed by a section on the pilot evaluation of the game, including the methodology adopted, the participants and the results. Finally, the main conclusions of the pilot evaluation, limitations on game design and its evaluation, as well as plans for future work are presented.

Analysis and Design of *Cells of War*

Cells of War is an offline card game presenting how the body reacts to intruders. The reasons why the specific subject was selected are:

- It is a multilevel complicated subject that is hard for students and people in general to comprehend by conventional means of teaching.
- There are quite few serious games engaging with the complex functionalities of the immune system.
- The micro-world of the cells and pathogens, the battle between them, as well as all the factors that can affect health, offer a lot of inspiration and a huge amount of gaming material.
- The specific context can be adapted successfully by a variety of game types, offering flexibility and freedom for the final choice of the game genre.

The design process that was followed is based on the Conceptual Framework by Yusoff et al. (2009) and the DPE Framework by Winn (2009), as already mentioned in the Introduction. The steps and the rationale behind every decision for the game mechanics are presented below.

Step 1: Define the purpose of the game

The first step into the design process is to define the *purpose* of the game. The *instructional objectives* were already presented at this article, so there is no need to list

them again. It is quite obvious that this game has an educational attitude. However, there is no debriefing functionality inside the game for the time being.

Once the player realizes how the immune system functions, he/she can also understand how the diseases affect the organism, as well as how the vaccines or medication contribute at that fight. Players can also comprehend how simple daily habits, nutrition and psychology can influence the general health in their own way. Eventually, all that knowledge may motivate the players to acquire a healthy lifestyle, to pay more attention to health issues and boost their well-being.

Step 2: Determine the game genre

In the design process of a serious game, the choice of an appropriate *game genre* is of high importance, as it will define both the resulted *playing and learning experience* for the player (Yusoff et al., 2009). Thus the learning object should fit the type of the game and align with its mechanisms. Otherwise, the game will lack harmony and fun, leading to a fail attempt to achieve the predetermined goals.

The nature of the immune system and the battle that is going on between white blood cells and pathogens, can fit to a variety of game genres, with each one of them resulting in different gaming experience and emotions for the player.

The game designed, is a turn based strategy card game. The reasons why this game genre was selected are the following:

- The concept of the battle between the two opposing fields is crystal clear. There is the pathogen acting as an invader, and the organism acting as a defender.
- Card games are well structured and have specific rules (Su et al., 2014). Thus, the rules of the functionality of the immune system can be easily integrated and define the rules of the game.
- They have simple game-play and mechanics, making them accessible to a wider range of age groups and gaming skills.
- A card game can have a defined duration and high replayability. Thus, by designing the game so as not to last more than 15 minutes, it can be played at different moments during the day and more than once.
- The replayability derived from the nature of the game is expected to enhance the learning outcome.

Step 3: Define the expected user experience

The game needs to be attractive for all age groups, including primary school students. As a result, the graphics should be simple, colorful and joyful. Although there are a lot of diseases in the game, the purpose is not to depress or stress the player about them, but rather to educate through a fun game.

According to the DPE framework (Winn, 2009), the player will judge if the game was fun according to the emotions it provoked. As a result the designer should be aware of

all the factors that provoke entertainment. Winn expands Garneau's (2001) 14 forms of fun to 16: beauty, immersion, intellectual problem solving, competition, social interaction, comedy, thrill of danger, physical activity, love, creation, power, discovery, advancement and completion, application of an ability, altruism, and learning. It is clear that a single game cannot provoke all the aforementioned emotions, or else forms of fun. The expected forms of fun for *Cells of War*, which result from the game genre and mechanics, are presented in Table 1.

Table 1. Expected forms of fun in *Cells of War*.

Form of fun	Way of achieving it during game play
Immersion	The battles that happen inside the game should absorb the player's attention, so when the game is over he/she would like to replay.
Discovery	For the first playthroughs the player is not familiar with the cards and the content of the game. As a result, in each round something new has to be discovered until he/she fully familiarizes himself/herself with the card content.
Learning	In case the game succeeds its goals, the player will feel the satisfaction of learning something new about the immune system, some diseases and some health issues in general.
Competition	Although there is no competition against another player, the player competes against the diseases and the final result will be either victory or loss.

Step 4: The learning material

Before defining the game rules and mechanics it is important to understand the *learning material* that will determine them. The immune system functions in a complex, multilevel way with a variety of cells and body mechanisms engaging the defense process. Under proper circumstances, a health expert should be part of this step however

that did not happen in this case. As a result, a deep research into the body mechanisms, white blood cells and diseases took place.

What came out is that the immune system functions in three levels. There is the *innate response* that consists of the anatomical barriers that prevent the invaders from entering the body, and the *white blood cells* that are the first to engage in battle in case a pathogen breaks in. There is also the *adaptive response* which is slower but specific.

Each cell that is part of the immune response has its own role and characteristics. All those were studied in order to create different card effects that match cells' functionalities. The exact same process took place with various viruses, bacteria, parasites and fungi, in order to determine the diseases that will be part of the game. In contrast with the cells, that are specific, there are many diseases that could be engaged into the game. There are also autoimmune diseases as well as chronic ones. Although, it was not possible to include all this material into the first version of the game, they will be part of the game content in later versions.

Last but not least, a research took place in order to determine how other *external factors* may affect health. Such factors include nutrition, sleep, exercise, drug abuse, alcohol and others.

Step 5: Integrate the instructional content into the gameplay

The most crucial step during the design process of a serious game is the integration of the learning material into the gameplay. The instructional content has to be part of the game, and it should not feel like an anomaly in the flow of it.

In this case, all the *game mechanics* and *rules* were inspired by the functionalities of the immune response. As a result, there are *three tiers* in which the player can play *cards*, representing the three levels of the immune system. Consequently, there are three types of “creeps” that will defend the player against the invaders.

The first type is the *barriers*. They can be placed in the first tier only when there is no ongoing battle. The second type is the *cells that belong to the innate system*. They can be played only when there is an ongoing battle. Finally, there are the *cells that belong to the adaptive system*. This tier gets activated only after a messenger cell called dendritic is played at the innate tier. The three levels of the immune response are shown in Figure 1.

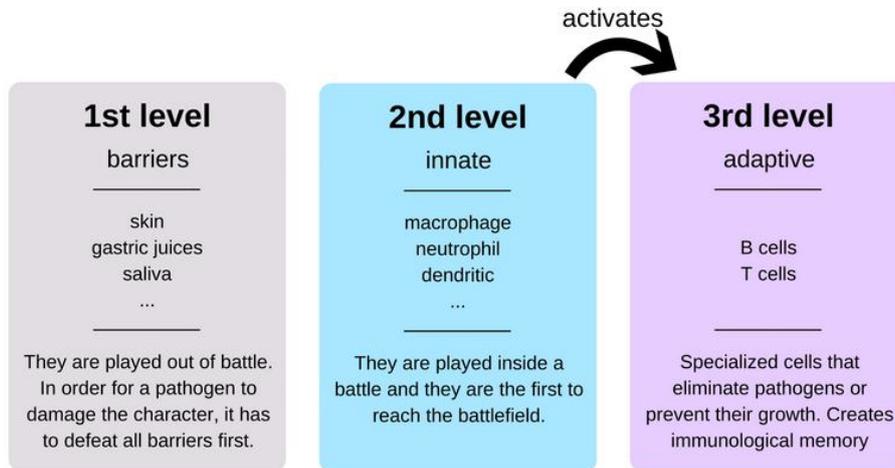


Figure 1. The three levels of the immune system.

The *immunological memory* belongs to the adaptive system. However, in the game the memory cells are held at a different level, as their presence is permanent. Memory B cells have the ability to “remember” the enemy and thus, when the player encounters a pathogen and there is already a memory b cell for it, then the battle is easier.

The rest of the factors that can affect health are integrated into the game either as *spell cards* or as *habits*. The former are cards that apply their effect the moment they are being played, while the latter are permanent cards that apply their effect at each round.

Finally, it should be declared that each card has a *special effect*, inspired by the real features of the item it represents.

Step 6: The game features and mechanics

As described at step 5, the learning content inspired most of the game features as well as all the card content. All the features and functionalities are presented in more details at Table 2. All these elements are placed into a single board which is shown in Figure 2.

Table 2. *Cells of War* game features and descriptions.

Feature	Description
Character	The character is the protagonist of the game. He is characterized by health, level and a special ability. The health maximizes at 50 and it is game over in case it reaches 0. The level also maximizes at 50 and it is the goal of the game to reach it. The special ability charges for 20% in each round, thus the player can use it once every 5 rounds.
Trouble	Trouble is considered the rival of the character. In each round a new trouble opens and in case it is a pathogen then the battle begins, otherwise the spell applies its effect and a new turn starts. Inside the battle the pathogen damages the character only when there are no barriers available.
Decks	There are two decks in the game. The one contains the character's cards, consisting of cells, barriers, good habits and good spells. The other one belongs to the troubles, consisting of viruses, bacteria, parasites, fungi, bad habits and bad spells.
Cards	All the cards are characterized by a name, a type, a description and a graphic element. There are two main categories of cards: the creeps and the spells. As creeps are considered the cells, barriers and pathogens and they are characterized by their life and attack points. As spells are considered the habits, medication, vaccines and other actions that affect the battle or the character. Each card has a special effect that can be applied at the end or start of the round, when it is played for the first time, when it takes damage or when it deals damage.
Hand	The hand is the cards available for the player to play. In each round the character draws a new card. The max hand size is 10 cards.
Tiers	The tiers are the place where the player plays cards to defend against the troubles. There are three tiers that accept different types of cards. The

first one is for the barriers, the second for the innate cells and the third for the adaptive cells. The barrier tier is active only out of battle. The innate tier is active in battle and the adaptive tier gets activated when a specific card is played on the innate.

Memory As the game progresses, the character may acquire immunological memory either by vaccination or by encountering a pathogen and activating the adaptive response. There are 8 slots for memory B cells. When the player encounters a pathogen for which there is already a memory B cell, then the adaptive tier gets activated and an Effector B cell is generated that lowers the enemy's attack and health stats.

Habits There are 6 available slots for habits. The good habits are being played by the player, while the bad ones are being drawn by the troubles' deck. Each habit applies its effect at the end or the start of each round.

Info Panel The info panel contains more information about the items in the cards. When the player hovers over a card then the details of it are shown in the info panel.

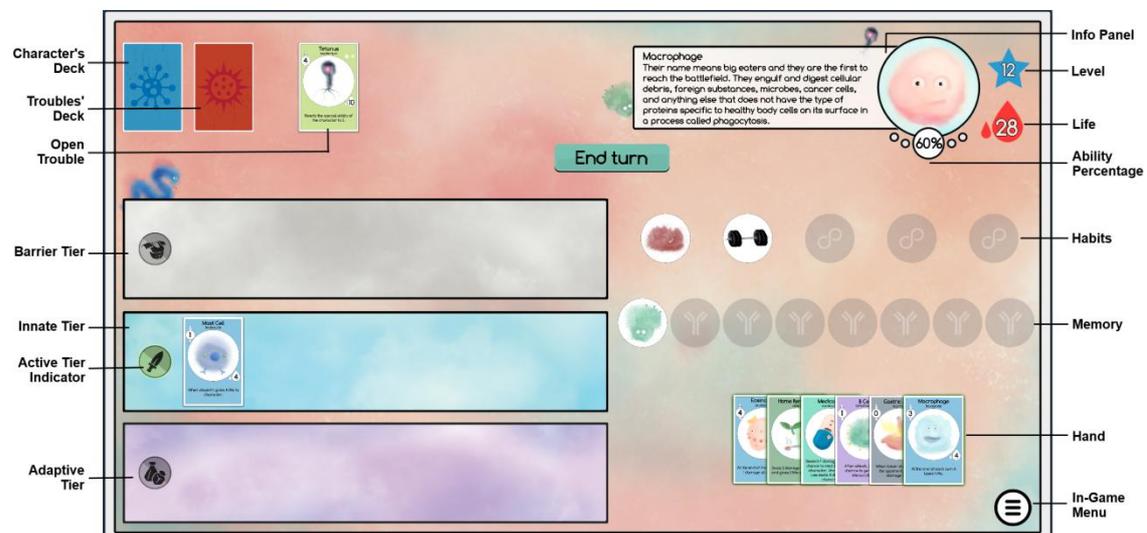


Figure 2. The board of *Cells of War*

The main element of the game is the cards. There are 2 main categories of cards and 12 subcategories, presented in Figure 3. Although the types for cells are leukocyte and lymphocyte, the player can easily distinguish between the cells of innate and adaptive system, as each card has a representative color matching the tier color. The Memory B cell is a type on its own, although it is a lymphocyte, because there will be multiple memory B cells on the game, for each pathogen. The design details of the cards are shown in Figure 4, where six cards are presented.



Figure 3. The card types of *Cells of War*.



Figure 4. Card type examples: barrier, leukocyte (innate), lymphocyte (adaptive), virus, other, habit.

The mechanics of the game are quite simple, and they are limited to drag and drop. The player can hover over any card in order to maximize it, and see the details of the card more clearly (Figure 5). In order for the player to play a card, he/she has to drag it, and place it above the corresponding tier in case it is a creep, or anywhere in the board in case it is a spell. Finally, the player can cast an attack by dragging a card that is already placed in any tier and target the enemy (Figure 6).

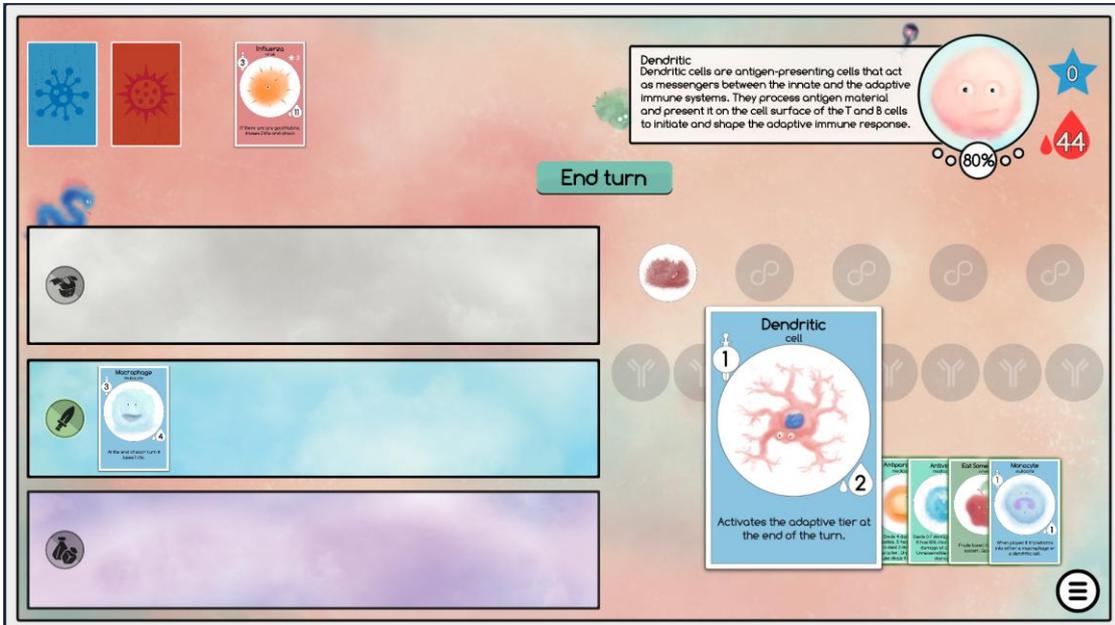


Figure 5. Game mechanics: Hover.

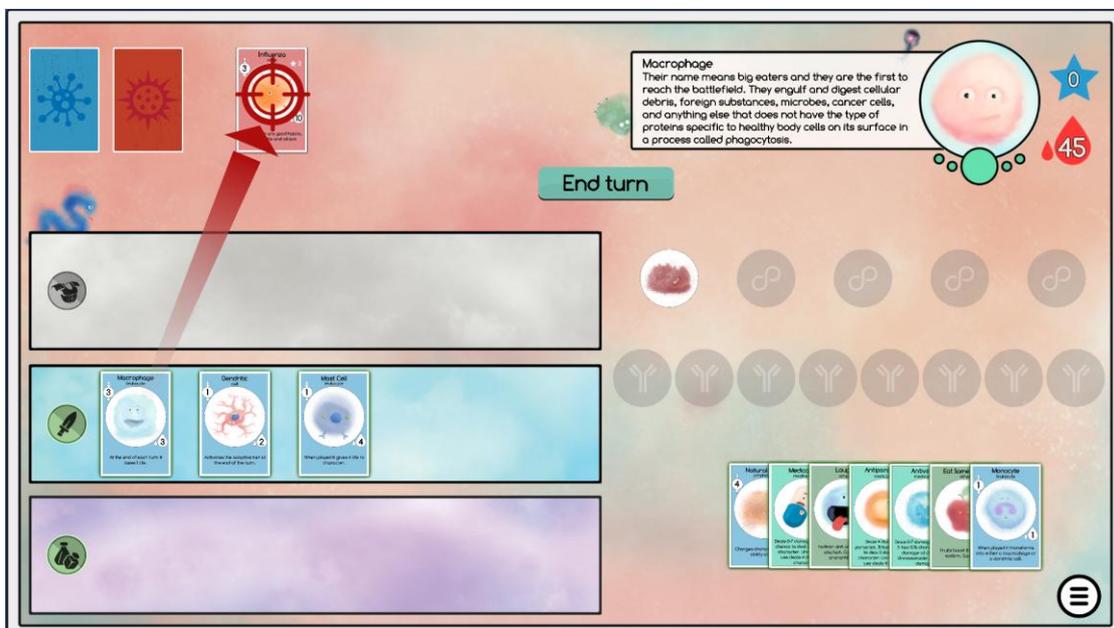


Figure 6. Game mechanics: Attack

Step 7: The game flow

The final step of the design process is to describe the *flow* of the game. When the game starts the character draws 5 cards. At the start of each round, a new card is drawn and there is no limit to the number of cards that the player can play, as long as they are playable at the specific game phase. If there is a battle going on, then only the innate tier is active and through a specific innate card, the adaptive tier can also be activated. Otherwise, the player can only place new barriers. Most of the spells can be played at all game stages, apart from some battle specific spells.

When the trouble's turn starts, a new card is drawn from the troubles' deck in case there is not a pathogen already open. If it is a spell, then it applies its effect and the turn of the trouble ends. Otherwise, the pathogen casts an attack at barriers or character and then ends its turn.

The winning factor is for the character to reach level 50, while the game over factor is when the health drops below zero. The character gains levels by killing enemies, or by playing spell cards and habits that offer levels. A more detailed game flow is shown at Figure 7.

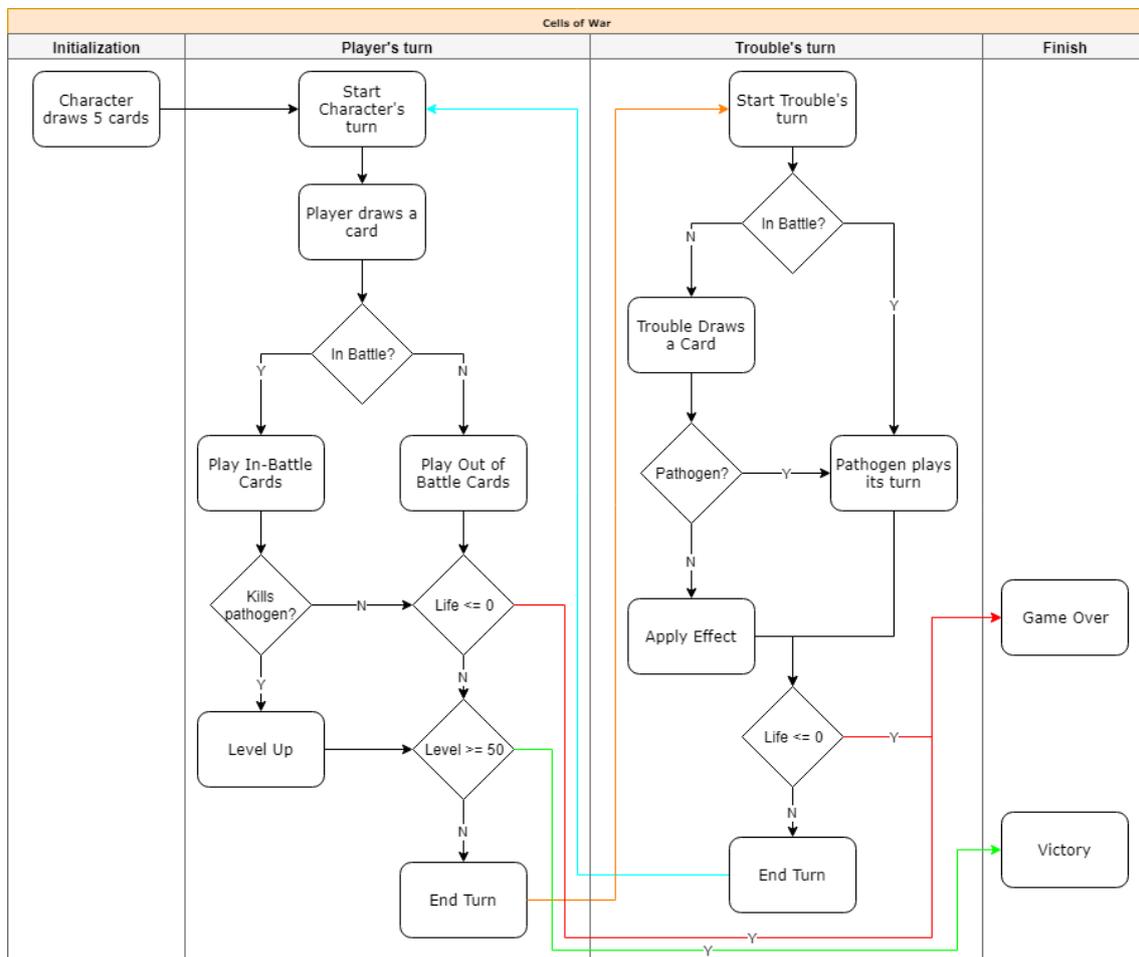


Figure 7. The *Cells of War* main game flow.

Pilot Evaluation of *Cells of War*

The evaluation of serious games and more specifically of educational games is considered to be of high importance, as it will provide information whether the game meets the required player experience as well as its learning goals. In this section, the methodology used and the results of the evaluation are presented.

Methodology

For the evaluation process of *Cells of War*, the MEEGA+ model was used (Petri et al. 2016), which evaluates the quality of educational games and contributes to their improvement.

The MEEGA+ evaluation model examines the perceived quality of the game and it is segmented in two main dimensions: the *player experience* and the *perceived learning*. Each dimension is analyzed into more sub-dimensions. The decomposition of all the quality factors is presented in Figure 8.

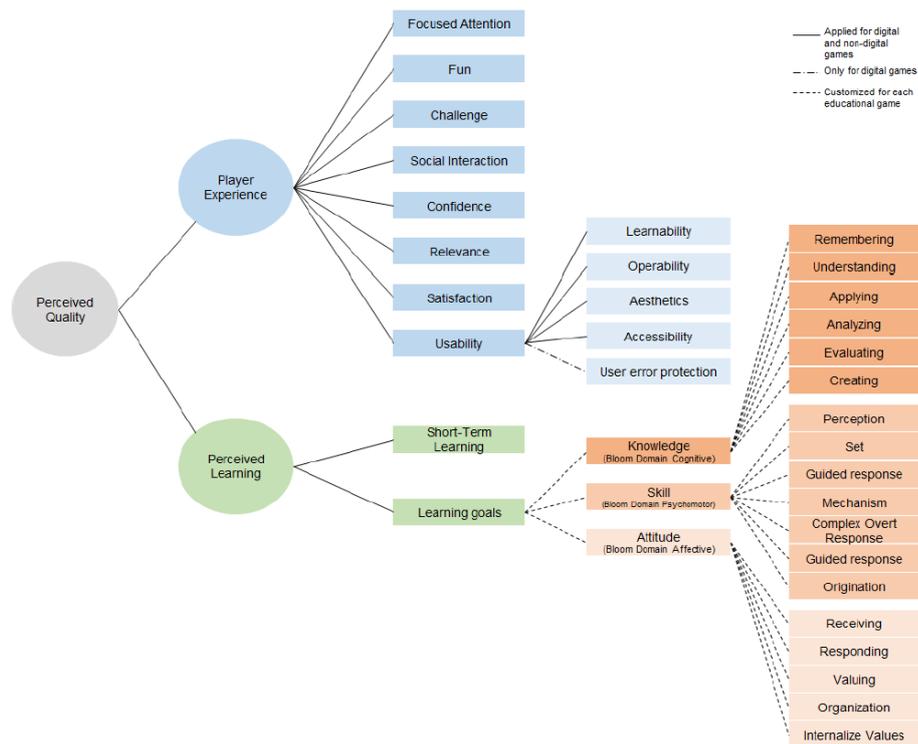


Figure 8. Decomposition of quality factors for the MEEGA+ evaluation model. *Source:* Petri et al. (2016).

Based on the above evaluation model, Petri et al. (2016) developed a measurement instrument which was eventually used in the pilot evaluation of *Cells of War* with a few modifications. The social interaction sub-dimension is excluded from the evaluation process as the questions wouldn't apply to an offline single player game. Two questions were added at the demographic section in order to extract information about the balance of the game. Finally, 5 questions were added to the learning goals sub-dimension in order to conclude the learning experience of the player.

The final questionnaire that was used for the pilot evaluation of *Cells of War* included:

- 6 demographic questions concerning the participants' gender, age range, periodicity of playing video games, prior knowledge on the immune system and win-rate on *Cells of War*.
- 28 questions about the player experience and 7 questions on perceived learning with a scale from -2 to 2 (-2 = strongly disagree, -1 = disagree, 0 = neutral, 1 = agree, 2 = strongly agree).
- 3 free text questions concerning what the participants did like about *Cells of War* and proposals for improving the game.

Participants

In the context of the pilot evaluation of *Cells of War*, an email was sent to BSc students that had attended a course on "Serious Games Programming" (Xinogalos, 2018), school teachers, health specialists and gamers inviting them to play the game and evaluate it

anonymously and voluntarily. Nineteen (19) participants downloaded and played the game at their home and then filled in an online questionnaire that was prepared using Google forms. Among the participants there were a primary school teacher, a health specialist, some gamers, former BSc students from the aforementioned course and people with a little or no experience in games. More demographic information for the participants is presented in the next subsection. This research has been conducted following the ethical requirements established by Greece national board of ethics.

Results

Demographics. The first part of the questionnaire, as already mentioned, consisted of demographic questions. The results of these questions are presented as pie charts showing the percentage for each possible reply in the corresponding question (and not the frequency). Figure 9 and Figure 10 present the gender and the age range of the participants. Figure 11 shows the periodicity of playing video games. Finally, Figure 12 presents the participants' prior knowledge on basic concepts of the immune system.

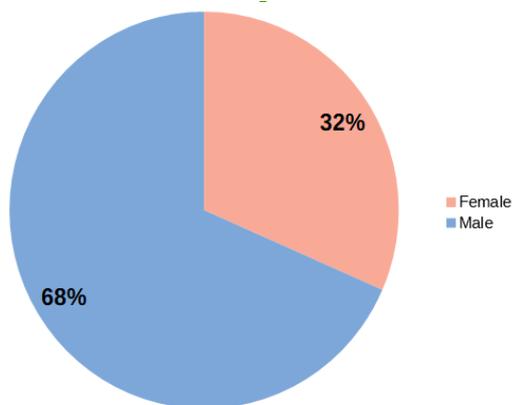


Figure 9. Participants' gender.

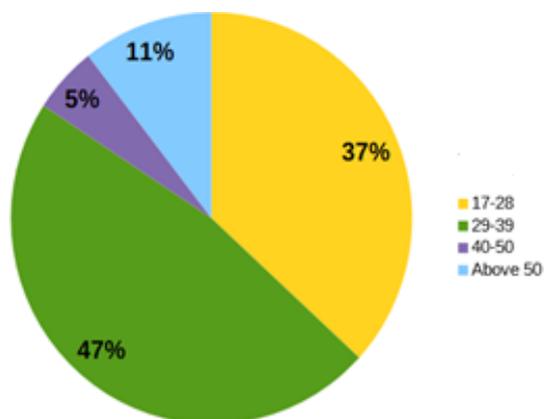


Figure 10. Participants' age range.

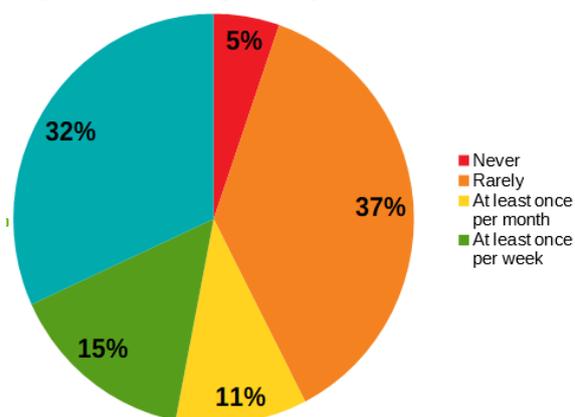


Figure 11. Periodicity of playing video games.

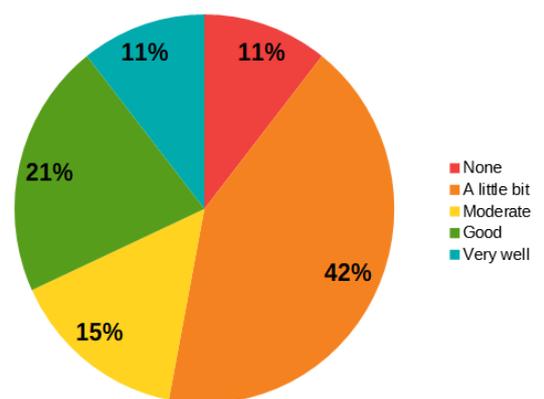


Figure 12. Prior knowledge on the immune system.

The range of ages indicates that there were no young students among the participants. As a result, the game was not evaluated for its appropriateness on a school environment. Nearly half the participants (47%) were between 29 and 39 years old, while a significant percentage (37%) of them was between 17 and 28 years old.

The next two questions refer to the number of times that the player did play the game before evaluating it (Figure 13) and the percentage of wins achieved (Figure 14). *Cells*

of War is a game based on replayability in order to achieve learning and consequently the balance of the game in terms of its difficulty is of critical importance.

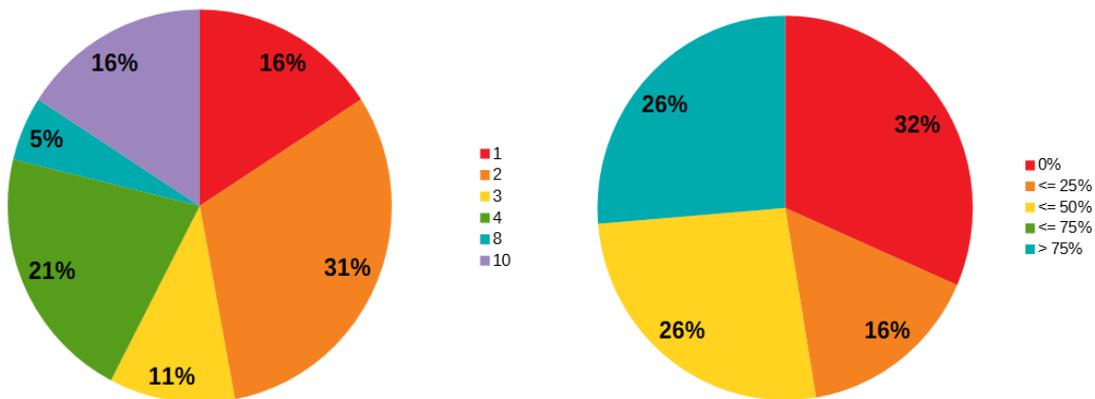


Figure 13. The number of times that the participants played the game. **Figure 14.** The win-rate on games played.

The results concerning the number of times that the participants played the game indicate that nearly half of the participants (47%) played the game once (16%) or twice (31%), while one fifth of the participants played the game 8 times (5%) or 10 times (16%). The average win-rate is 39.74%, which indicates that the game is quite challenging. This result is also supported from the relevant questions regarding the challenge posed by the game that are included in the second part of the questionnaire that deals with the player's experience.

Player Experience. Concerning the player experience, Figure 15 presents the results for the different quality factors of the MEEGA+ evaluation model. The results indicate that

the participants enjoyed the graphics and the aesthetics of the game (47% strongly agreed and 42% agreed that game design is attractive), although the adaptation to the gameplay was not easy for the most of them (32% agreed, 47% were neutral and the rest disagreed that learning to play the game was easy). As the majority of the comments in the open question point out, there should be better instructions for the game, in the form of a tutorial. The results on the fun dimension show that the game was fun to play (58% of the participants agree and 16% strongly agree), however it did not succeed to immerse the players. Specifically, one fourth of the students (26%) stated that they were so involved in playing that lost track of time, while just one tenth of the students (11%) forgot about their immediate surroundings while playing.

Overall, as can be easily seen in Figure 15 the majority of students evaluated positively the following factors: aesthetics, accessibility, confidence, challenge, satisfaction, fun and relevance. Learnability, error prevention and recovery, as well as focused attention were less positively evaluated.



Figure 15. The player experience related results

Perceived Learning. Figure 16 shows the results regarding the perceived learning of the participants. The majority of the participants reported that they did learn something new by playing the game (32% agree and 36% strongly agree), although they did not consider the topic of the game important to them. Specifically, just 11% of the participants considered the topic important for them, 63% of them were neutral and the rest 26% did not consider the topic important for them. This indicates that although the participants were not motivated enough to gain knowledge on this topic, the game attracted at some degree their interest since 63% of them spent time on reading the extra info (educational content) provided during game play and finally 68% of them stated that learned something new on the topic.

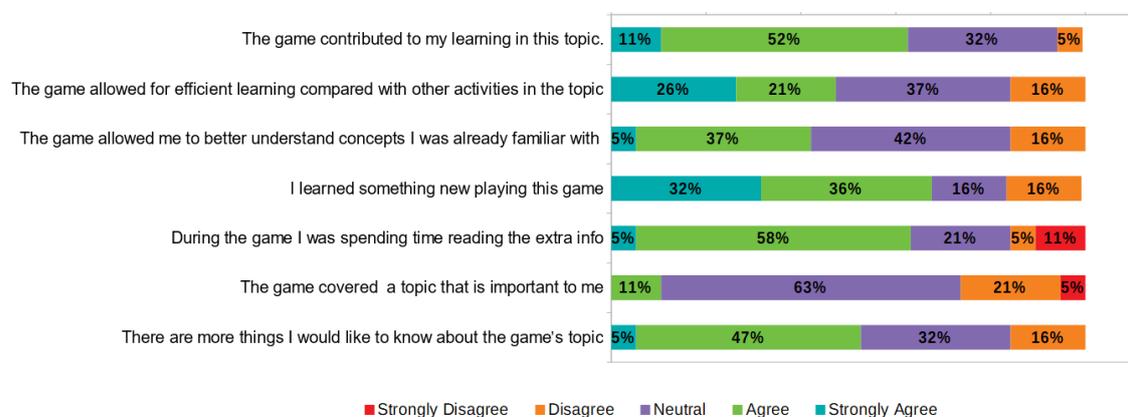


Figure 16. The perceived learning related results

Comments and Suggestions (open questions). The majority of the participants noted some of the strongest aspects of the game according to their experience. Among their

comments were the graphics and the character designs, the gameplay, the contribution on learning the functions of the immune system and the importance of the topic. A few of them stressed out that the game is fun, friendly and challenging. Some participants also mentioned that the game can be used to a wide range of ages.

Finally, most of the players suggested improvements for the game. Several participants commented on the absence of a good tutorial. They also asked for more explanations during the game concerning things that can or cannot happen. Although there are indicators on cards and tiers pointing out the playable ones, they asked for more distinct demarcation. Two of the participants also suggested more vivid colors. There were also proposals for more attractive effects, enriched content, less content, and information concerning the three tiers. Finally, one of the participants suggested that the game should be simpler, as it seems complicated.

Conclusions

Cells of War is an educational card game aiming to introduce the players in the micro-world of cells and pathogens, familiarize them with the defense mechanisms, inform them on how different habits may have an impact on their health and finally motivate them to pay more attention on health issues.

The game was evaluated by 19 participants of different knowledge and gaming backgrounds in terms of player experience and perceived knowledge. The game was

evaluated positively by the majority of the participants in terms of player experience and more specifically in terms of the following criteria: aesthetics, accessibility, confidence, challenge, satisfaction, fun and relevance. An interesting result regarding the perceived learning of the participants lies in the fact that although the majority of them had no (11%) or little (42%) knowledge on the way that the immune system functions and just 11% considered the topic important, the majority of them studied the incorporated educational content (63%) and stated that they did learn something new by playing the game (68%). This is an indication that the game can help, even people that are not interested in improving their health activities, to gain some knowledge on the topic. However, it is clear that finding ways for highlighting the importance of the topic to potential players and motivating them to learn through playing *Cells of War* is necessary. This might be easier to accomplish with smaller aged students that have not yet shaped their beliefs and health-related activities, but this is just a hypothesis that has to be studied.

Based on the results of the pilot evaluation the following changes and improvements were implemented into the game: a video tutorial replaced the textual instructions, which came out that did not support the majority of students in learning to play the game easily (learnability factor); the player can now hover over the icon of each tier in order to read information about it; the glows of the playable items became more distinct.

Besides, these improvements there are several features that could also be implemented in the game to improve the player experience and make the game more challenging, engaging and motivating. These features combined with proposals from the participants of the pilot study are presented in Table 3.

Table 3. Future work – improvements of *Cells of War*.

Feature	Description
Characters	The game would be more interesting if there were more than one character to choose from, with different deck compositions and special abilities. Giving the player the ability to create his/her own deck could make the game even more engaging.
Levels	The game could be more attractive and challenging with a leveling system. Each game can provide the player with points depending on how many diseases were beaten, in what way, and whether the game was victorious or not. By leveling up, the game could become more challenging and difficult. Also, more game features, abilities or characters could be unlocked by reaching specific milestones.
Achievements	The feature of achievements is widely used by most of the commercial games in order to motivate the players. This mechanism could also be implemented into <i>Cell of Wars</i> and their completion could grand the player with levels or new features.
Cards	The topic of the game provides inspiration for many more cards, types of cards and abilities. The player could unlock more cards as he/she progresses into the game, levels up or beats achievements.
Content	There is more content that could be integrated into the gameplay as new features. Autoimmune diseases or other chronic diseases could increase the difficulty of the game by affecting the battles and the abilities of the cells, as well as the way that habits affect the character.
Features proposed by the participants of the pilot evaluation	<ul style="list-style-type: none"> • Addition of a view where the character can inspect all the cards in the game. • Addition of a counter that informs the player on how many cards are remaining in the decks. • Addition of the game's settings in the in-game menu so that the player can adjust the language and the sound during game play. • Reporting in-game messages explaining why an action cannot

	take place. <ul style="list-style-type: none">• Addition of a tutorial introducing the player into the game.• Existence of more music tracks.
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Finally, it would be important to carry out an evaluation of *Cells of War* with more participants and even more important with teachers and students in order to study the learning impact of the game on young players.

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