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Viral.izo: A game-based learning to foster resource management skills against emerging viral attacks

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Abstract

This work presents *Viral.izo* 2.0, a casual educational game favouring world health by acting against emerging viral attacks. It extends our previous work by including three new game levels of progressive difficulty and two new minigames. In addition, we created three new variants beyond the original virus. Each variant has a specific visual design, attack behaviour (damage power and speed of spread), and visual effects. Knowing how to manage resources against the unpredictability of the virus and its variants is crucial for survival. We also developed a ranking system and new menu options to increase player engagement and game competitiveness. Moreover, we conducted new evaluations using a metric for assessment of user experience, showing that *Viral.izo* is capable of educating while challenging the player.

Keywords: *Game-based Learning, Health Awareness, Health Promotion, Resource Management, Virus, Ranking, User Experience*

1 Introduction

New coronaviruses (COVID-19) emerged in China in 2019, with higher infectivity, as reported by Zhu et al. (2020). This virus massively spread across Europe and the Americas, affecting mainly the United Kingdom, Italy, France, Spain, Germany, the United States, Mexico, Brazil, India, and Russia, characterizing a pandemic of great concern for the global public health. Currently, around 220 countries and territories have already been severely affected by COVID-19, as stated in WorldoMeters (2021).

Consequently, 2020 was a year full of worldwide awareness campaigns on ways to prevent this overwhelming pandemic. Digital games have then emerged as a means of entertainment, occupation, and health promotion, helping maintain many's mental health, especially of children and young people, amid frequent lockdowns. Game company leaders delved into campaigns to encourage gamers to follow World Health Organization guidelines. Among the most relevant actions, one can mention social distancing, hand hygiene, and respiratory etiquette, among others, in accordance with the World Health Organization (2021).

By mid-2021, more than 186 million cases of COVID-19 infection had been confirmed worldwide, and more than 4 million deaths, according to the World Health Organization (2021). Regarding Education, more than 1.5 billion students and young people around the planet have been affected by the closure of schools and universities during the pandemic, as informed by UNESCO (2021).

Various technological solutions in digital games have been developed, proving it is possible to build knowledge, engage, and exchange knowledge in the face of a severe health issue, such as the unprecedented recent pandemic.

Figure 1. *Viral.izo* 2.0 game start screen

In this manuscript, we extend our previous work by Santos et al. (2021) presenting *Viral.izo* 2.0 (**Figure 1**), a casual educational game for general audience for the sake of world health and against the rampant proliferation of a virus. We added three new virus variants (player's enemies) in this game version. In addition, each enemy has a unique visual appearance and behaviour, including specific damage powers and spreading speeds. We also developed a local ranking system to create a more competitive play. Moreover, we added three new levels of increasing difficulty with unique visual effects to engage the player and offer new possibilities for experiencing and learning how to manage health resources against the fast virus proliferation, its harmful effects, and unpredictability. Furthermore, we added two new minigames between the last two game levels. These minigames work as health boosters to help the player complete the game levels, making it possible to earn bonuses according to the player's performance. Finally, we conducted new User Experience (UX) assessment testings with sixteen users applying the Calvillo-Gámez et al. (2015) CEGE questionnaire.

2 Related Work

Although the subject being relatively new, some educational games for health promotion have been proposed in the context of the current pandemic of the new coronavirus. The works presented in this section were collected as part of the *Viral.izo*'s game project design methodology. This survey began with a broad search for digital games with a contagious disease central theme. Among these, we then selected those focused on educational games that presented characteristics related to the main ones idealized for our game: simple but engaging graphic visuals, easy gameplay, increasing levels of difficulty, and a reward and progress system.

Facens et al. (2020) developed *Heroes of the Pandemic*, an educational game about ways to prevent COVID-19, including minigames. Each stage features a specific mechanic with different visuals. It has a 2D *cartoon* style, with varied animations, and offers an *online ranking* system that can be linked to *Facebook* to share match results on social networks.

Andrade (2020) designed *Virus Combat* (originally named *CoronaGame*) and caught the attention of the Brazilian Ministry of Health, conforming to the World Health Organization (2021). It has elements of biosecurity standards, such as wearing masks, washing hands with water or alcohol gel and maintaining social distance. Initially, its focus was on fighting the COVID-19 virus, but *Google Play* adapted its strategy to the policy against the disclosure/promotion of catastrophic death-causing events. However, the enemy remains a virus that can provoke losing the game upon contacting the character controlled by the player.

Corona Prevention is an educational memory game focused on the COVID-19 prevention, by Triângulo and Alto Paranaíba (2020). The player can flip several cards by clicking the *mouse*. These cards reveal to the player a way to prevent/protect people when two cards match their patterns. This game has simple 2D graphics in the *cartoon* style, and it is casual and designed to be played individually.

Weber (2020) conceived *COVID-19 Game*. The player must collect as many masks and alcohol gel tubes as possible to gain ammunition, particularly vaccines to throw against the coronavirus to destroy it. In addition, the player can do Ammo reloads. This game presents scenarios in Brazil attacked by COVID-19. Each level is named after a healthcare professional: the player starts as a nursing technician and, if successful, at the end of the game becomes a specialist doctor. This game is casual, minimalist, in the 2D *cartoon* style.

Campos and Ramos (2020) implemented *Plague Inc: The Cure*, a game aimed to save humanity from a new virus. To this end, the player leads a world health organization with several initiatives. Each player's decision strongly influences the course of the game. For example, if the player tries to start a quarantine with little popular support, this initiative will have serious consequences. It is a 2D game categorized as a real-time strategy with simulation traits.

Venigalla et al. (2020) proposed *SurviveCOVID-19*, a game that aims to educate about biosecurity measures in the face of the COVID-19 virus and how to survive through the collection of food products and medicines get these items in the game's scenario. It is a 2D game, in pixelated format, with simple motion control mechanics. While collecting items, it is necessary to wear a mask and self sanitize to avoid being infected. With a time limit for doing so, the player wins the game when all the items are collected, safely returning home. In a similarly themed game (but in 3D), De Oliveira et al. (2020) presented a game in which the player, in the role of a health agent, has the mission of identifying and distributing face masks to people walking around without masks. Furthermore, the health agent gives instructions to passersby about prevention measures to contain the spread of the virus, such as avoiding crowds, the importance of social distancing, etc.

Machado and Carvalho (2018) created *Immuno Rush*, a tower defence style game, where the player must protect the human body by acting as an immune system commander. Enemies, represented by viruses, bacteria and protozoa, are trying to invade the human body. Thus, the player must devise defence strategies to prevent this invasion, building towers expressed by immune system cells. The game has five stages, increasing difficulty levels and immune system number of elements to fight microorganisms, which, in turn, become even more diverse and resistant.

Agar.io is one successful example of a game known worldwide that is simple-to-play, competitive, multiplayer, with *online* action and easy control mechanics, by Lindsey (2019). Each player controls a cell on a map representing a cylindrical and flat container used for the culture of microorganisms to acquire as much mass as possible and, thus, avoid becoming another bacteria's lunch or until "swallowing" smaller cells, that is, other players. As it collects mass, it gets bigger and bigger, making the player move slower and slower.

All these related works influenced the development process of the *Viral.izo* game, but its main inspiration came from the *Virus Combat* game, a reference to fighting emerging viral attacks. Also, the *Viral.izo* ranking system had as reference the ranking styles from *Agar.io*, *Heroes of the Pandemic*, and *Immuno Rush* games that feature the players with highest scores. Unlike the rankings of these online games, *Viral.izo*'s ranking system runs only locally. The strategy of collecting items to prevent and fight COVID-19 is also a vital tool in our game, similarly to those used in the games *Virus Combat*, *SurviveCOVID-19*, and *COVID-19 Game*. Having the *COVID-19 Game* as a reference, we conceived the levels of *Viral.izo*, based on the idea of generating increasing difficulty with the need to get essential features linked to the COVID-19 theme, such as vaccines at particular areas of the game's maps. The *Corona Prevention* game also served as a basis for the minigame we implemented in which the player has to order significant COVID-19 historical events. However, instead of identifying a collection of identical cards, in our minigame the player is challenged to read and order the COVID-19 historical events listed on the game screen. In addition, the way of moving cells and the logic of collecting items and eliminating enemies from the *Agar.io* game –to gain as much mass as possible by swallowing smaller cells and thus fighting enemies without being destroyed–, were also inspirational for the *Viral.izo* design process.

Finally, the games presented therein approach the facts (disease process and its spread and combat when applicable), aiming to inform and educate by its rules in different ways. Regarding visual effects, all of them make use of animations to help to immerse the player in the game's scenario, thus, engaging players and adding to the gameplay. *Heroes of the Pandemic* uses levels to introduce the main ways to prevent COVID-19 and the most common symptoms of this disease, such as shortness of breath and high temperature. Each phase ends with the presentation of information on the subject in focus, helping to strengthen knowledge about the coronavirus. *Virus Combat* challenges the player not to come into contact with the virus by collecting and using preventive items, similar to real-world initiatives, such as wearing gloves and masks. Regarding the card memorization game *Corona Prevention*, when the player hits an identical pair of cards, textual information is displayed to the player with helpful information to prevent the coronavirus. *COVID-19 Game* is centered on the coronavirus and addresses vaccines and social distancing without focusing on educational aspects, but on entertainment. *Plague Inc: The Cure* informs about the existence of COVID-19 and preventive measures, simulating a pandemic. The player has the opportunity to learn and implement different initiatives against the virus based on solutions tried in the real-world pandemic, such as social isolation to slow the spread and fight the virus and application of vaccines. *SurviveCOVID-19* focuses on promoting biosecurity measures against COVID-19. The player is encouraged to collect products for their survival during the pandemic, wear masks and constantly sanitize hands to avoid spreading the disease. In *Immuno Rush* the player can learn a little about combating microorganisms by correctly positioning the immune system's defences. Unlike *Viral.izo*, this game is not directly related to COVID-19 and does not have the same gameplay style as *Viral.izo*. It is based on the tower defence style, while *Viral izo* portrays antibody-fighting viruses according to their sizes and the game items consumed around the maps. To conclude, compared to *Viral.izo*, *Agar.io* does not present distinct game phases, a system of items related to COVID-19 to be collected, or visual effects conceived to stimulate player engagement and educational purposes related to fighting diseases.

3 Methodology

We conceived *Viral.izo* in a critical and sensitive period during the lockdown period of the COVID-19 pandemic. It was a year of many uncertainties, in which one of the co-authors of this work, with more than 20 years of practice in academia and 11 years of experience in game design and development, led the development of this project remotely.

After analyzing some related works and motivated by the idea of defeating playfully a virus that has been cruelly decimating the human population around the world, we conceived the core idea of *Viral.izo*. Due to time restrictions (only six months to develop the first playable version of the project), we decided that *Viral.izo* would be a casual game having 2D maps depicting the city of Fortaleza, the State of Ceará, Brazil and the world as basic scenarios. To make the game more interactive and provoke a more impactful player experience when combating the virus, we shaped the core idea, having the player (the game protagonist) visually modelled as a cloud of antibodies. This cloud of antibodies would encompass the smaller viruses, increasing in size, and could eventually neutralize the virus and win the game. From this starting point, we created the game history to contextualize how the antibodies' cloud came to the Earth to help save the human population.

The solutions modelled and implemented in our game are part of a complex domain which typically needs successive revisions and feedback. Thus, the methodology used to develop *Viral.izo* had as an ally recognized practices in the area of Software Engineering and agile methods. These well-known practices guided the game's stages of development, with remote meetings, frequent discussions and alignments, the definition of work groups, activities, and the production of software and art artefacts, requiring expertise and continuous creative invention, as well as synchronism from all team members. The game's art and design were created from the requirements analysis phase, followed by the implementation, verification and validation phases.

Based on several meetings with the game team members, we documented the initial ideation in a Game Design Document (GDD), which guided all the development activities. More specifically, among several important documents, we produced: an overview of the game (concept, graphics, audience, level of interactivity, number of levels, enemy profiles, game objects, combat forms, ranking system), gameplay and mechanics (game progression rules, structure, objectives, game flow, special effects inspired by Fonteles et al. (2014), spawn control of game objects and their dynamics, movements and control mechanics through maps using navigation and policy layer as done by Barbosa and Rodrigues (2006) and Silva and Rodrigues (2009), actions, strategies to fight viruses with some studies inspired by Rodrigues et al. (2014), menu options and interface), the story behind the game (art and design, assets, plot, storyboard, relationship between characters), camera control, sound effects, music score and system help, the definition of an Artificial Intelligence (of viruses, NPCs, collision detection system and map trajectories), technical considerations about target platforms for game execution, the game engine to be used and image editing software and scripting language. Finally, we also defined how we would perform the tests with participants and which strategies we would use for analyzing the results.

Each phase contemplated in the GDD was developed iteratively, with the result evaluated in detail through exhaustive functional tests. To ensure team productivity, we managed team members into Product Owner (PO), Scrum Master (SM) and developers, where the PO and SM interacted directly and constantly with the project coordinator to define activities and prioritize them in a backlog. The execution of activities, from the highest to the lowest priority, was divided into sprints for better monitoring.

We detailed raised the minimum requirements for the game from the initial idea. *Viral.izo* should be a game to be played on a computer, with the main character controlled interactively by the player, capable of educating the players and promoting health, with simple but appealing graphics to all ages of the target audience. The game's development phase followed these requirements. Regarding the visual art, the choice of the colour palette was based on the colours green and blue, reflecting the feeling of hope in the health and safety areas, respectively.

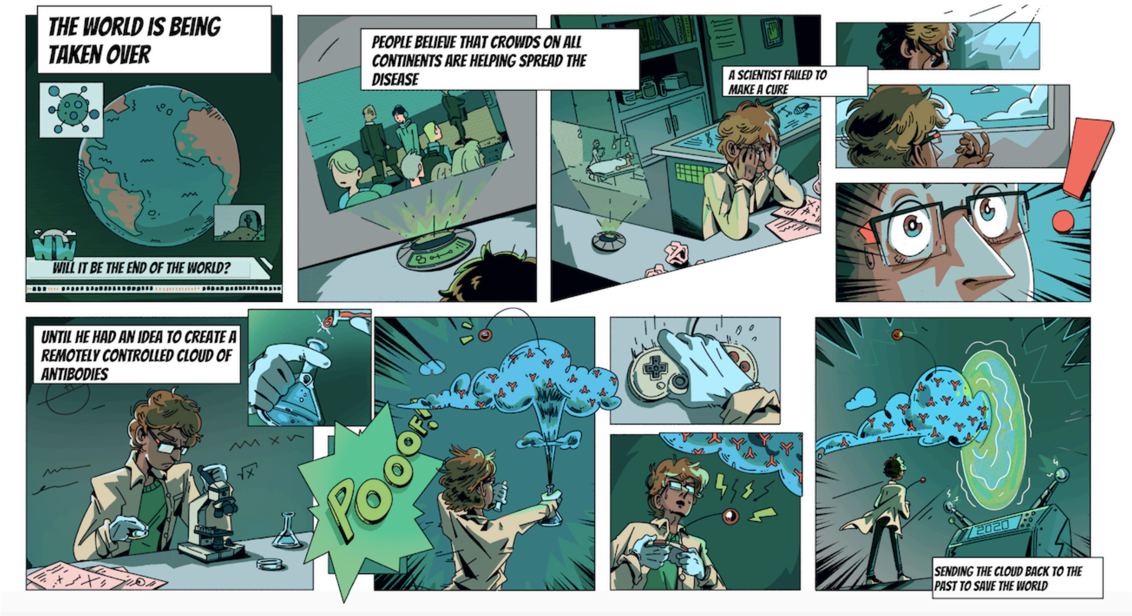


Figure 2. Opening scene of *Viral.izo*

We designed the levels of the game after setting the minimum requirements we wanted for the project, aiming to achieve all goals and especially to create the best possible experience for the player, following our previous work central idea presented in Santos et al. (2021). First, we defined that the movement of the antibody cloud would be free by the game maps with the virus pursuing it. Then, to facilitate the player-game interaction, we modelled the camera as a static object to stimulate a greater immersion perception in the real-time interactive battles against the viruses. Finally, after brainstorming ideas, we implemented a local ranking score to make the game more competitive to players.

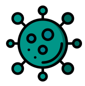
4 Game Overview

We used the *Unity* game engine to implement *Viral.izo* (version 2.0), as well as previous experience in developing casual games as detailed in De Macedo and Rodrigues (2011). In addition, we also created a collection of new *scripts* in C#, programmed to insert the new features of the game. In the next sections, we will present the plot and opening scene of the game, the 2D graphics & design, the gameplay details, and the local ranking and score systems.

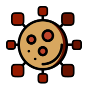
4.1 Plot and Opening Scene

The primary motivation for playing the current version of *Viral.izo* is the following mini plot, shown in the game opening scene (**Figure 2**):

> *"A pandemic virus and its variants are attacking the world. Moreover, scientists believe crowds on all continents are helping to spread the disease quickly. In particular, one of the scientists created a cloud of antibodies to avoid people's agglomeration and defeat the viruses. Furthermore, this scientist can control the cloud remotely by sending it back to the past to save the world."*

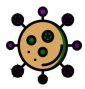


(a) In level 1: The original virus, with default speed and damage power.

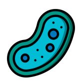


(b) In level 2: First variant of the original virus, faster and with greater spreading power.

(c) In level 3: Second variant of the original virus, more aggressive and with greater damage power.



(d) In level 4: Third variant of the original virus, simultaneously faster and more aggressive with greater spreading and damage power.



(e) In all 4 levels: Bacteria.

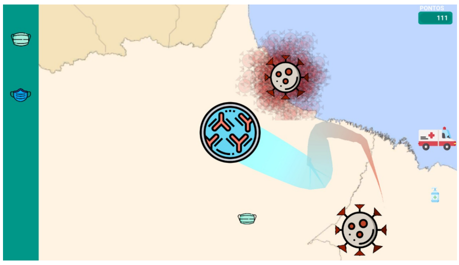
Figure 3. The main enemies in the *Viral.izo* game: the original virus, its three variants, and the bacteria

4.2 2D Graphics & Design

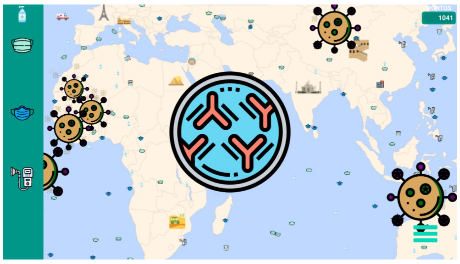
The 2D graphics based on the maps and inventory of collectable items from the original game developed by Santos et al. (2021) have remained. However, we included in the colour palette of *Viral.izo* (version 2.0) additional shades to visually represent the new three virus variants created (**Figures 3.b, c,** and **d**). These variants act as the enemies in the three new game levels implemented, *i.e.*, 2, 3, and 4. In particular, each of the new variants also has a specific visual *design*, attack behaviour and visual effects linked to it

(a) Visual effects of the original virus

(b) Visual effects of the first variant



(c) Visual effects of the second variant



(d) Visual effects of the third variant

Figure 4. Some of the visual effects generated with the Unity particles system for the virus and its three variants

(**Figure 4**).

There is yet another enemy in the game, the bacteria (Figure 3.e). While the interaction of the antibodies cloud with the virus and its variants portrays a kill or die relationship, the interaction with the bacteria causes much less significant damage, not leading to death. However, it causes a loss of strength, visually represented by slightly decreasing the antibodies cloud's size at contact.

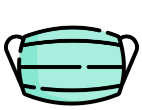
Moreover, we created two new visual effects for the player's trajectories along with the 2D maps by customizing them as a trail left using the same colours of the antibody's cloud, as shown in Figures 3.b and c. The smaller the cloud size, the faster the player moves around the map and the greater the accuracy. The smaller, the quicker the player moves across the map. Consequently, the greater the trail left. As presented in Rocha et al. (2006) and Serpa and Rodrigues (2020), dynamic collisions in real-time among objects provide more visual realism and entertainment for representing interactions. Thus, we modelled the interactions among the antibody cloud with other game objects (viruses and their variants) using Unity's particle system. In addition, we customized the particle system to represent different visual effects dependent on the existing enemies sprite present at that level (Figure 4).

More specifically, the virus has a spherical, black emission. On the other hand, the second variant emits a circular visual effect every second, with the same colour as the original virus, but with a transparency effect. The third variant is cone-shaped and coloured red. Finally, we implemented the fourth variant using a shape similar to a "doughnut", customized with a yellowish shading. The virus and its variants use their respective sprites (Figure 3), with the particles fading over time.

Viral.izo was conceived to offer an easy mechanic with a clear objective. It contains elements of the real world at a global level: personal protection items (some of them are shown in **Figure 5**) and 20 varied tourist spots, illustrative of agglomeration points. We included in the game the descriptions of each personal protection item collected in the game scene and its importance for world health for educational purposes as stated in Santos et al. (2021).

In version 2.0 of *Viral.izo*, we also developed two new minigames to allow the player to gain additional in-game bonuses. These minigames have visual art that adheres to the game's theme. They were included between the level change from 2 to 3 (Minigame 1) and from 3 to 4 (Minigame 2). Minigame 1 presents an educational game using cards containing events related to the pandemic experienced in the period from 2020 to 2022, which must be ordered chronologically; while Minigame 2 is an endless runner, in which the player, armed with the second dose of the vaccine, must evade the viruses and their variants.

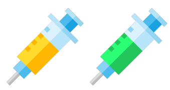
Finally, the music score and sound effects used in the current version of the game are the same as in the original game by Santos et al. (2021).



(a) Simple mask

(b) PFF2/N95

(c) Face shield

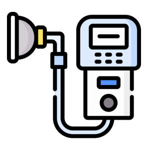


(d) Vaccines

(e) Gel alcohol

(f) Elmo

(g) EVA



(h) Ventilator

(i) Ambulance

Figure 5. Collectible in-game items. Icons are from free stock images created by Eucalyp (2021), Freepik (2021), and Smashicons (2021)

4.3 Gameplay

Figure 6 shows the main flow diagram of the gameplay. Currently, the game has 4 levels. In addition, in *levels 2 and 3* we unlock two different minigames that help players earn health bonuses to fight against emerging viral attacks. In particular, the scientist is the character who triggers the minigames to help the player earn bonuses and get prepared for the levelling up, as shown in **Figure 7**.

The player controls the antibody cloud using the *mouse*. Thus, the antibody cloud will always follow the path taken by the player's *mouse*. The level of control complexity grows with advancing the game levels. The camera's field of view automatically adjusts to the size of the antibody cloud, i.e. the size of the "player", to suit the proportions of the player and the game's maps. In this version of *Viral.izo*, the player can pause the game by pressing the button in the lower right corner of the screen or by clicking the ESC key. There are three new options of buttons on the pause screen: replay, go to the game home menu and help with the control mechanics.

At *level 1*, the primary enemy (the original virus character of *Viral.izo* 1.0) and the antibodies cloud spawn on the map of Fortaleza, Brazil. Over the course of the match, the antibodies cloud must collect a variety of items, which spawn randomly. These items vary by shape, rarity and bonus types. For example, some of them can increase the antibodies' cloud size or speed, double the player score and even give an extra life. The antibodies cloud can collide with the enemy virus. Whenever this happens, if the size of the virus is greater than the size of the antibodies cloud, it is defeated, and the game ends (**Figure 8.a**). However, if the antibody cloud has already collected the item "Elmo" (Figure 5.f), it can be used as a strategy for the player to gain an extra life, allowing the game to continue. If the antibody's cloud size is larger than that of the virus, the latter is destroyed, and the former increases in size. This logic is maintained throughout the game.

The antibodies cloud levels up to *level 2* when it reaches a predefined maximum size, migrating to a scenario that presents the map of Ceará, in Brazil. At this level, in version 2.0 of *Viral.izo*, we implemented variant 1 of the virus with a higher spreading speed. We also increased the number of spawns and the speed of this variant by 25% compared to the original virus. At *level 2*, the antibody cloud has a mission to collect an essential new item, the "vaccine" (first dose), needed to unlock *level 3* in the game. Additionally, due to the higher level of gameplay complexity caused by the more harmful behaviour of variant 1, in the game's narrative, the scientist who is remotely working in his laboratory interferes in the game to help the player, as shown in Figure 7, triggering Minigame 1 (**Figure 9**).

More specifically, Minigame 1 is a card game played with 16 cards. Each card depicts a historical event associated with the pandemic, with the date information in which that event occurred but hidden from the player. We selected the main 16 pandemic events for use in this game according to the information published in OPAS (2021), Sanar (2020), SP1 (2021), De Moura (2020), Brandão (2021), Ministério da Saúde, Brasil (2021), Galvani (2021), as follows:

1. WHO was alerted about cases of pneumonia in the city of Wuhan (December 31, 2019).
2. Chinese authorities confirmed the identification of a new type of coronavirus (January 7, 2020).
3. WHO declared a Public Health Emergency of International Concern, the highest alert level (January 30, 2020).
4. The pandemic virus was named SARS-CoV-2 (February 11, 2020).
5. The WHO considered COVID-19 a pandemic (March 11, 2020).
6. The Ministry of Health in Brazil announced the first death from COVID-19 (March 12, 2020).
7. The first Brazilian patient diagnosed with coronavirus was cured (March 13, 2020).
8. The Ministry of Health gathers a record of hospitalizations of suspected and confirmed cases of COVID-19 (April 14, 2020).
9. Anvisa approves rapid tests for COVID-19 in pharmacies and drugstores (April 28, 2020).
10. The new equipment named "Elmo" was used with success on patients with COVID-19 in Fortaleza, Brazil (June 26, 2020).
11. The Delta variant reached recorded cases in India (December, 2020).
12. Anvisa granted the registration of the Pfizer-BioNTech vaccine (March 23, 2021).
13. Anvisa approved the emergency use of the Janssen vaccine against COVID19 (March 31, 2021).
14. The World Health Organization validated the CoronaVac vaccine for emergency use (June 1, 2021).
15. South Africa reported the emergence of the Omicron variant to the WHO (November 24, 2021).
16. Anvisa granted the registration of the Fiocruz/AstraZeneca vaccine (December 3, 2021).

Minigame 1 starts displaying a table with only 8 historical events, among 16 events registered in the game dictionary. If the card was placed correctly with the date in chronological order with all other cards on the table, the card stays in place and the card's background changes from light green to dark green (Figure 9.a). The player wins when placing the 8 cards correctly, that is, there is no try; otherwise, the player loses, the minigame is over and the card's background turns completely red (Figure 9.b).

Initially, we created a dictionary that has as keys the numbers from 1 to 16 and the values that are the historical events, represented by sentences. We use an array of values from 1 to 16 to store event cards and shuffle them. Then we take the first eight positions of this scrambled vector and sort it. Following, we check each of the buttons associated with each event card, passing the corresponding values available in the dictionary to them. As long as there are cards to click, we take the event displayed on the card and search for it in the first eight positions of the ordered vector. If the player makes a mistake in the chronological order of some event no point is earned and the card turn red. However, the player earns scores from 0 to 16 bonus points for each correct click in the card's event done in chronological order.

At the end of *level 2*, having reached a pre-defined maximum growth size, the antibody cloud can move to *level 3*, which has the map of Brazil as the background and a new virus, the second variant. This variant has a more aggressive damaging power. We implemented this behaviour as follows: even when the antibodies cloud size is larger than the variant one and manages to defeat it, the antibodies cloud decreases

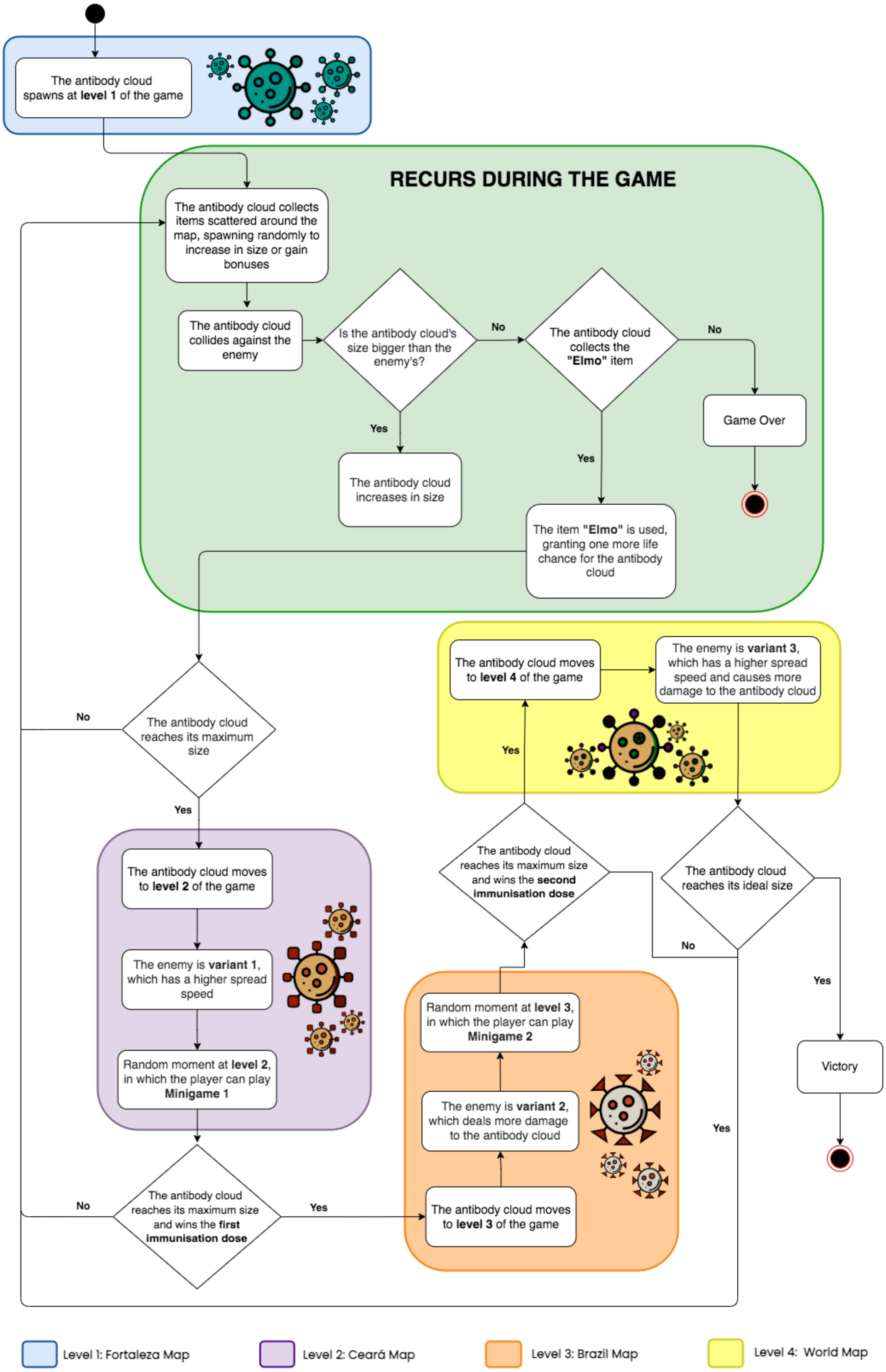
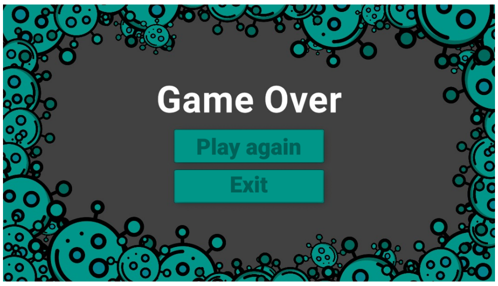
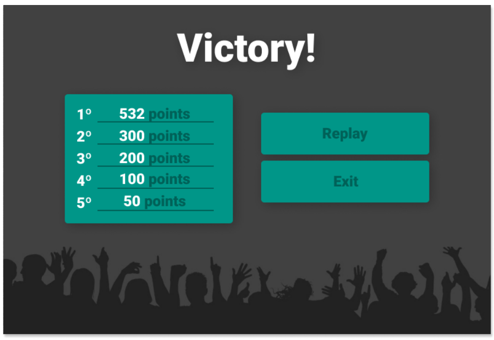


Figure 6. The flow diagram of *Viral.izo* (version 2.0)

Figure 7. A message pops up on the map from the scientist working remotely to help the player gain a size bonus to fight the virus and its variants. If the player accepts the challenge, Minigames 1 and 2, on the game *levels 2* and *3*, respectively, will initiate

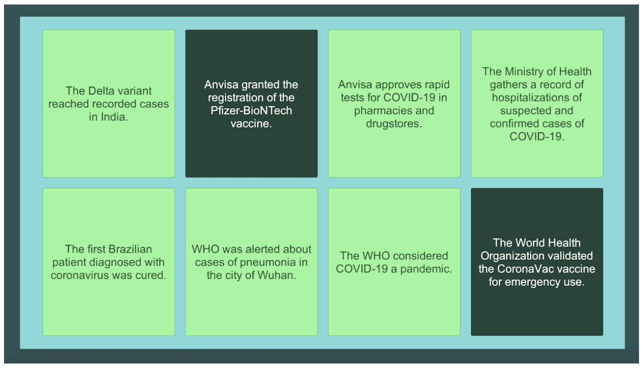


(a) Game over screen, the player has been defeated

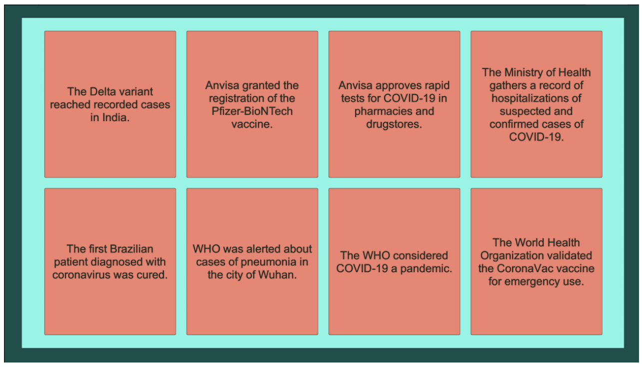


(b) Victory screen, with final ranking and player scores

Figure 8. Game over and victory screens



(a) Opening screen with cards displaying random sentences of temporal events that happened during the pandemic, with two card events selected correctly in chronological order (in dark green)



(b) Game over screen

Figure 9. Example of screens from Minigame 1

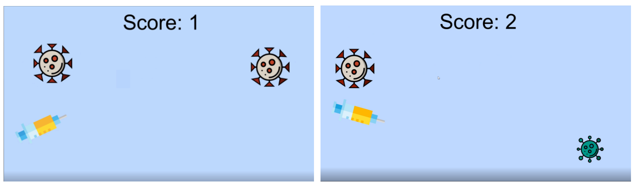


Figure 10. Some keyframes in temporal sequence from the timeline of Minigame2, with player's scores

in size instead of increasing (as what occurs in the two predecessor levels), losing points, hence strength. Moreover, due to the more harmful behaviour of variant 2, again, the scientist remotely interferes to help the player, this time, triggering Minigame 2 (**Figure 10**).

Minigame 2 is an endless runner in which the player controls a vital character, the second vaccine dose which has to evade the enemies, *i.e.*, the viruses and their variants over time. We implemented Minigame 2 in such a way to inherit the behaviours of the virus and variants from the main game, making it possible to display a smooth transition of animations in syntony with the general gameplay. Furthermore, we implemented a camera speed rate that increases with time, proportionally to the time the player remains immune from colliding with the game enemies, making the match increasingly complex. In particular, the scientist is the character who triggers the minigames to help the player earn bonuses and get more potent. This minigame ends when the vaccine hits any virus or variant. After that, the antibody cloud receives bonus points proportionally to the duration of time the player gets invincible in the minigame.

Finally, *level 4*, the last one in the game, is released when the antibody cloud reaches an even larger size, having already collected at *level 3*, the other crucial survival item: the second dose of the vaccine. The final scenario is illustrated by the world map, with a new and final variant 3 as the great enemy. Variant 3 has a behaviour that is a mixture of those from variants 1 and 2, with greater spread and damage power. The antibodies cloud must reach a new maximum size defined for this game level to win the game. Upon successful completion of *level 4*, the player wins, and a victory screen is displayed, with ranking and player scores, as shown in the table of **Figure 8.b**.

4.4 Local Ranking and Score Systems

To make the game more attractive to replay, we have also implemented a local player ranking system in *Viral.izo* (version 2.0). Basically, through the game's menu (start screen, Figure 1), the player can access the score at runtime. Alternatively, upon completing *level 4*, winning the game (victory screen, Figure 8.b), the player score will be recorded locally, allowing access to the ranking screen, which, in turn, displays an ordered list of the best scores. To implement this feature, we use serialization and JSON. For each game match, scores are saved in a vector, and the vector data is used to generate the ranking. The ranking system displays only the five best scores and counts only the matches the player finished and survived. The total score value depends on the number of items collected throughout the game and the player's health status. In particular, the player's score is directly proportional to the size of the antibody cloud, *i.e.*, the larger it is, the higher the player's score.

5 UX Assessment Testings

5.1 Participants

Initially, the *Viral.izo* developer team and a senior developer, who was not involved in the *Viral.izo* game development, conducted functional tests to identify inconsistencies and execution failures. As a result, possibilities for improvements were placed. The team then revised the implementation to reduce the risk of execution failure and provide a better gaming experience.

In a later phase, we conducted UX assessments with 16 (sixteen) participants aged between 20 and 32 years, 15 undergraduate students and 1 graduate student in Computer Science from the University of Fortaleza (UNIFOR). After briefly explaining the game's purpose and the control commands to be used during the game session, we carried out the tests running the game on a notebook.

Following the game experience, each participant answered the 38 questions of the Core Elements of Gaming Experience (CEGE) questionnaire created by Calvillo-Gámez et al. (2015), plus two more subjective questions: one about the game in general and the other about the two minigames in particular. The general questionnaire was prepared by one of the co-authors of this work and made available to the subjects via a *link* to the *Google Forms*.

5.2 Questionnaire

The CEGE questionnaire has a 7-point Likert scale where 1 means *Strongly Disagree* and 7 means *Strongly Agree*, as proposed by Calvillo-Gámez et al. (2015), as follows.

1. I enjoyed playing the game
2. I was frustrated at the end of the game *
3. I was frustrated whilst playing the game *
4. I liked the game
5. I would play this game again
6. I was in control of the game
7. The controllers responded as I expected
8. I remember the actions the controllers performed
9. I was able to see in the screen everything I needed during the game
10. The point of view of the game that I had spoiled my gaming *
11. I knew what I was supposed to do to win the game
12. There was a time when I was doing nothing in the game *
13. I liked the way the game looked
14. The graphics of the game were plain
15. I do not like this type of game *
16. I like to spend a lot of time playing this game
17. I got bored playing this time *
18. I usually do not choose this type of game *
19. I did not have a strategy to win the game *
20. The game kept constantly motivating me to keep playing
21. I felt what was happening in the game was my own doing
22. I challenged myself even if the game did not require it
23. I played with my own rules
24. I felt guilty for the actions in the game *
25. I knew how to manipulate the game to move forward
26. The graphics were appropriate for the type of game
27. The sound effects of the game were appropriate
28. I did not like the music of the game *
29. The graphics of the game were related to scenario
30. The graphics and sound effects of the game were related
31. The sound of the game affected the way I was playing
32. The game was unfair *
33. I understood the rules of the game
34. The game was challenging
35. The game was difficult
36. The scenario of the game was interesting
37. I did not like the scenario of the game *
38. I knew all the actions that could be performed in the game

Where * Denotes items that are negatively worded: 2, 3, 10, 12, 15, 17, 18, 19, 24, 28, 32, 37.

The two additional subjective questions were the following: 1. Would you like to include any suggestions or criticisms to improve this game? If yes, please write below; and 2. Did you get any bonus playing Minigames 1 or 2? Any comments about these minigames?

5.3 Results

We analyzed the 38 answers obtained from the CEGE questionnaire, and calculated a numerical result for each core element of the game experience from the 16 participants' responses, represented as pie charts, as shown in **Figures 11**, **12** and **13**. We used two colour gradations to generate the pie charts, depending on the 7-point Likert scale associated with their respective colour intensities.

For the positively worded items (**Figures 11** and **12**), we used shades of green ranging from lighter to darker ones, in sequence representing *Strongly Disagree*, *Disagree*, *Somewhat Disagree*, *Neutral*, *Somewhat Agree*, *Agree*, and *Strongly Agree* ratings. To differentiate, for the items negatively worded (**Figure 13**), we coloured the pie charts in shades of blue which varied on the other hand, from darker to lighter ones, representing, in the following order, *Strongly Disagree*, *Disagree*, *Somewhat Disagree*, *Neutral*, *Somewhat Agree*, *Agree*, and *Strongly Agree*.

For positive questions (Figures 11 and 12) and focused on the occurrences of *Strongly Agree*, *Agree*, and *Somewhat Agree* scores, one can notice that the majority of the charts show much more darker shades of green than lighter. Also, the extreme scales are related to Enjoyment, which means the players, in most cases, enjoyed the game. The highest scored question was item 26 (Graphics), with 87.5% *Strongly Agree*, and 12.5% *Agree*. The lowest was item 35 (Game Difficulty), reaching 6% of *Strongly Agree* and 6% of *Agree*, meaning that participants did not find the game difficult to

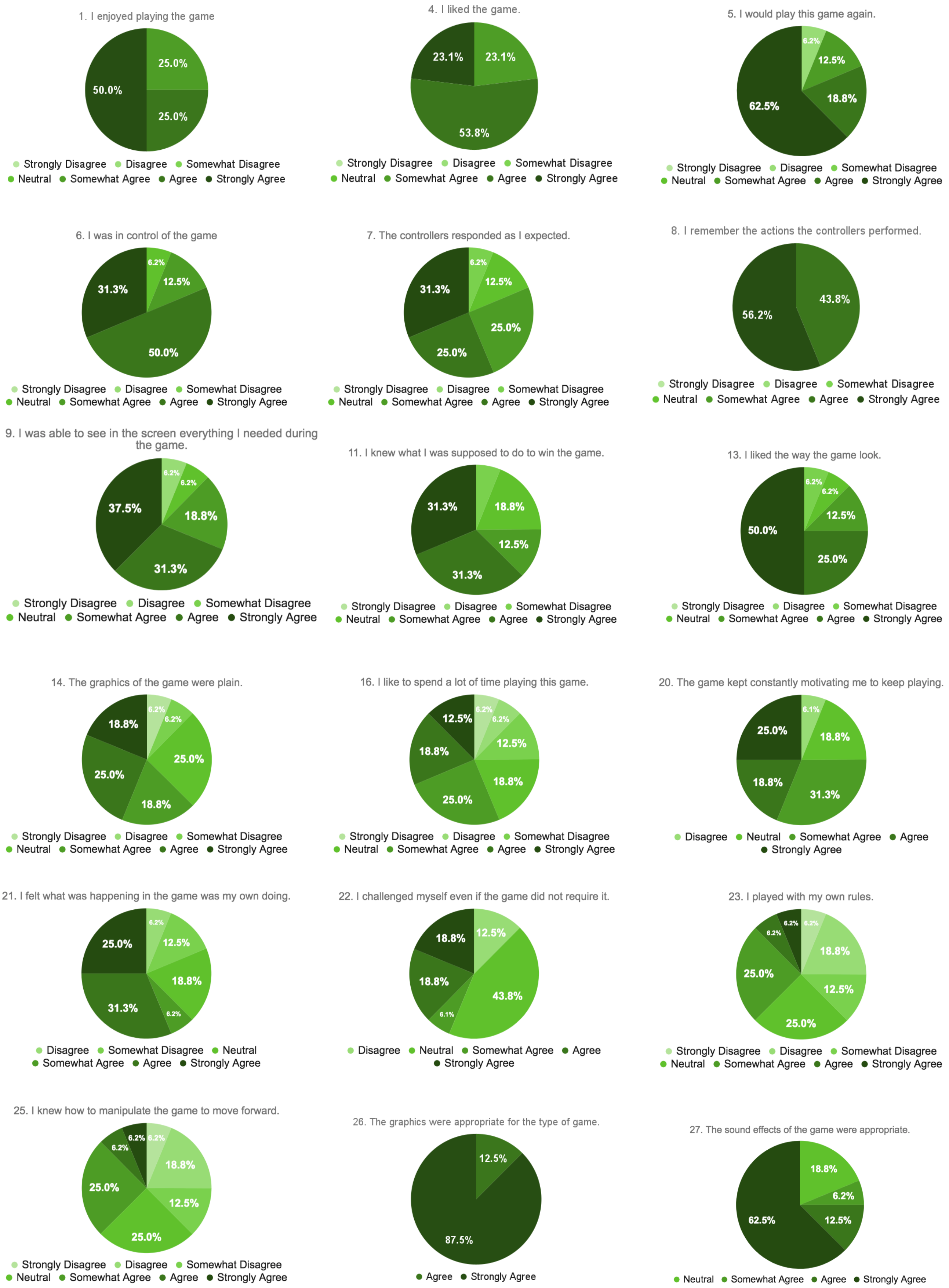


Figure 11. Part I of raw results from the CEGE questionnaire by Calvillo-Gámez et al. (2015), where each question (positively worded) was answered using a 7-point Likert scale

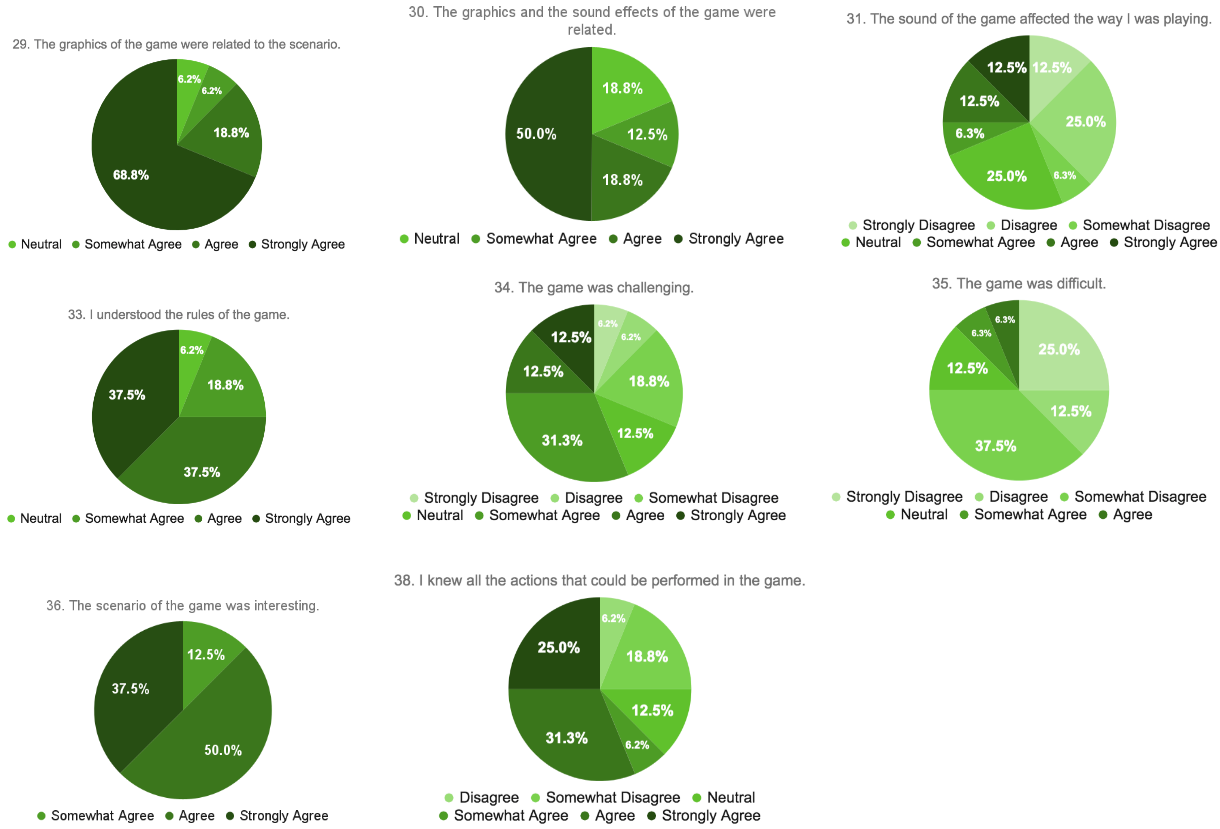


Figure 12. Part II of raw results from the CEGE questionnaire by Calvillo-Gámez et al. (2015), where each question (positively worded) was answered using a 7-point Likert scale

play. For the negative questions, in general, related to Frustration, most of the pie charts show darker shades of blue than lighter ones (*i.e.*, *Strongly Disagree*, *Disagree*, and *Somewhat Disagree*), which means that Frustration was not a problem when playing this game. The more diverging scoring scales are observed for questions 18 (Game genre choice) and 19 (Player's strategy to win).

In addition, we quantified the average (A) and the standard deviation (SD) for the overall 38 CEGE questions. The results for the overall positively worded items are pretty average (A=5.68, SD=2.0), and the negative ones are slightly lower (A=3.0, SD=1.67). The SD for both is very close to each other. Also, **Figure 14** shows the quantified A and the SD for each of the 38 CEGE questions. Only statement 35, "The game was difficult", had an average value close to 3 (*Neutral*). Many of the negatively worded statements (exhibited with bars red-coloured in Figure 14) had the highest standard deviation, perhaps because they confused the reader. In particular, subjects responded affirmatively to statements 18 and 19, respectively, "I usually do not choose this type of game" and "I did not have a strategy to win the game". These answers can indicate they do not commonly play casual games similar to *Viral.izo* or did not have access to all the instructions to play the game as they wanted to have. However, the instructions given to participants about playing the game were intentionally minimalist to evaluate how instructive is the current gameplay implementation of *Viral.izo*.

From the additional two questions, we learnt many lessons from the subjects' criticisms which were very positive and constructive. For example, some participants suggested adding the time spent playing until victory and the score on the same ranking screen. Another suggestion was implementing the game using an online multiplayer mode and lowering the antibody cloud reward when collecting the pff2 mask. Also, some subjects had difficulty when playing Minigame 1 and, thus, experienced game over. They suggest calibrating this difficulty level better so that the player could have, for instance, two extra lives to enjoy this minigame better and learn more from the card contents about the pandemic. Positive comments reinforced that the two minigames are very fast, appear by surprise and provide bonuses, generating more adrenaline in the game. Two more conservative players preferred not to risk playing the minigames and continued the game focused on passing the four phases without additional bonuses. Other subjects commented that more detailed instructions about the minigames could help the player not quickly make mistakes. However, in general, players found both minigames fun and challenging, mentioning that they offer the opportunity to earn bonuses and power up at vital moments in the game before returning to the primary battle on the map to defeat the variants and level up until reaching victory. From this analysis, we conclude that the overall average results were very positive and that all the raised issues by participants and their suggestions about how *Viral.izo* can be improved will help the development team revise and polish future versions of the game.

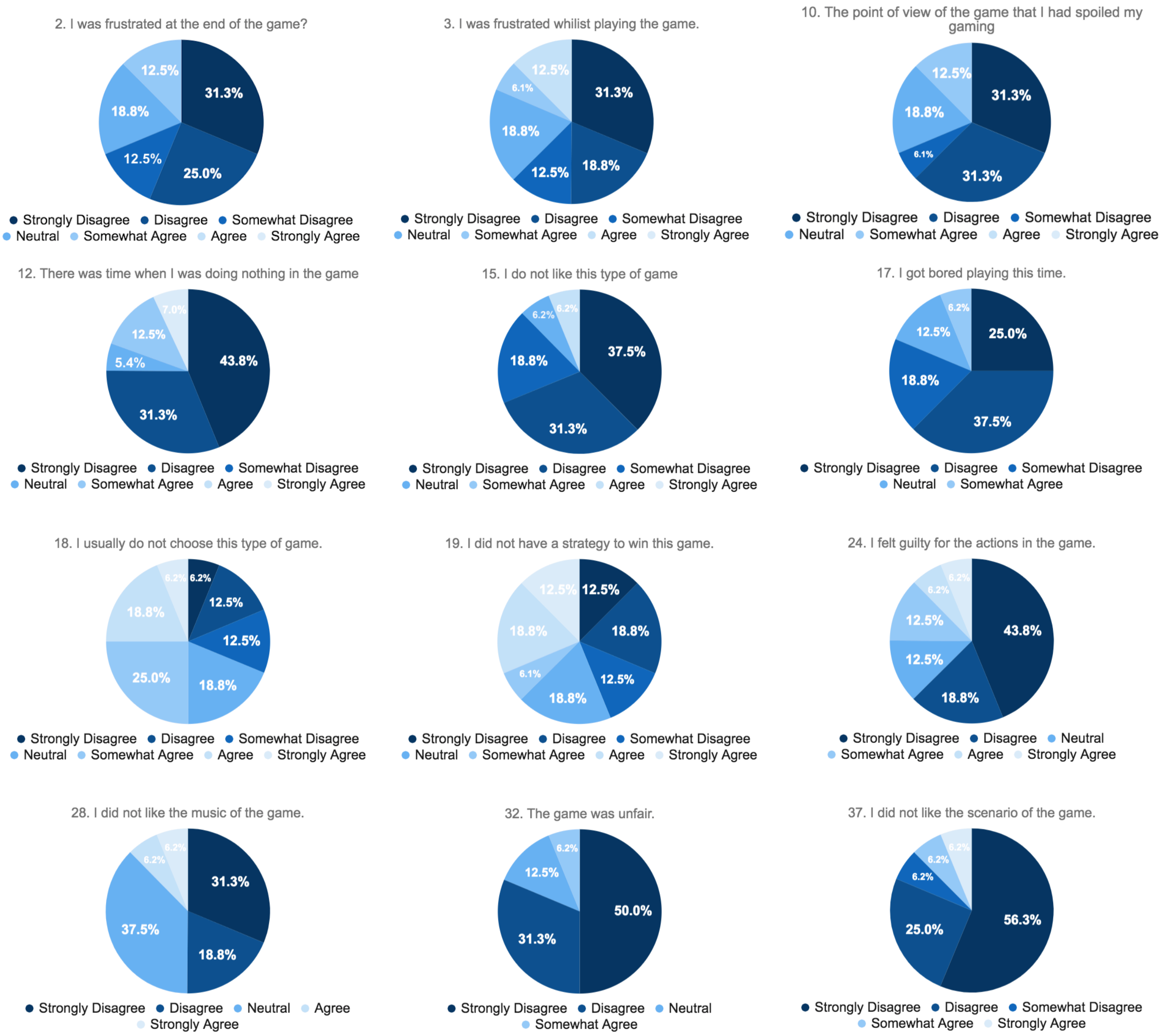


Figure 13. Raw results from the CEGE questionnaire by Calvillo-Gámez et al. (2015), where each question (negatively worded) was answered using a 7-point Likert scale

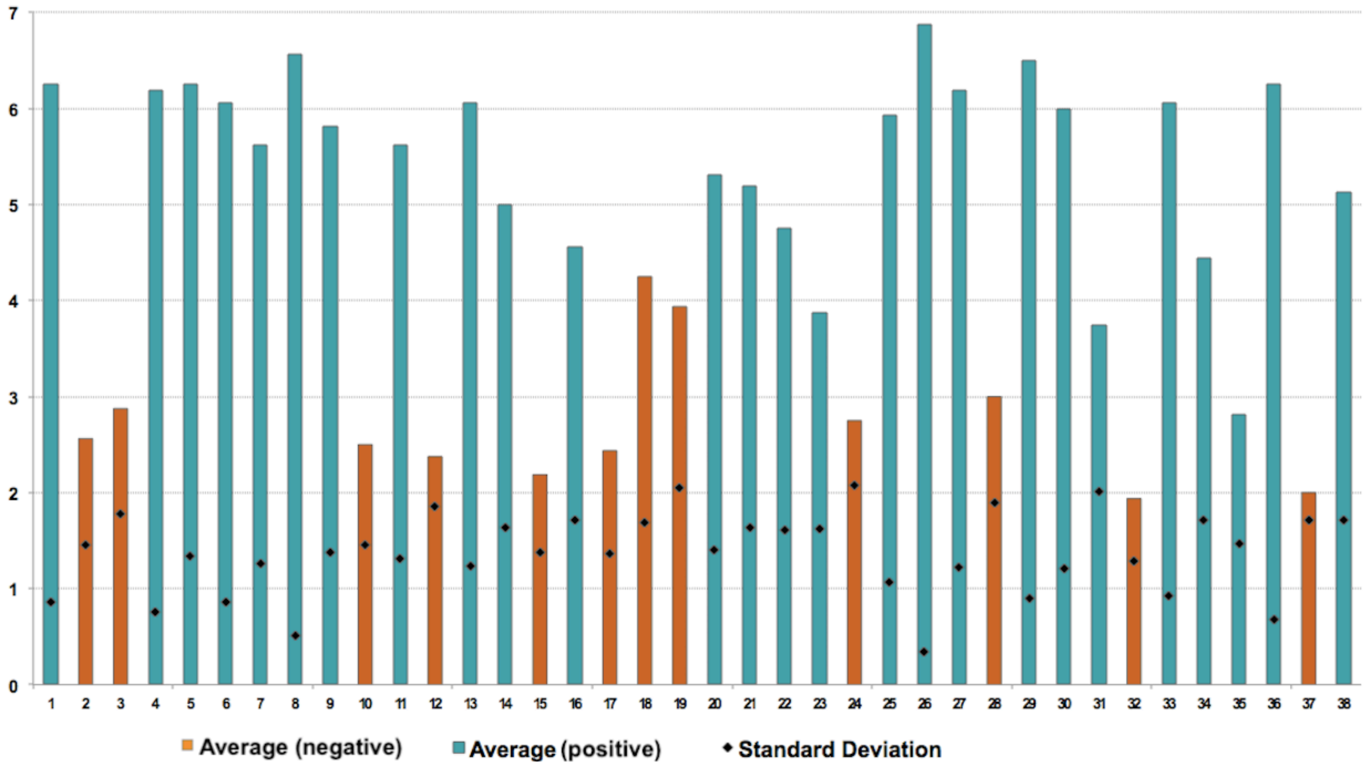


Figure 14. Average results and standard deviations calculated from the CEGE questionnaire by Calvillo-Gámez et al. (2015), for each question answered using a 7-point Likert scale

6 Conclusion and Future Work

The aim of a digital game is not to simulate real life, but to offer a unique experience of play according to its set of rules. Historically, animations, films, and digital games have been applying the exaggeration principle to visually push actions further to add more drama and appeal to the scene. In general, less exaggeration creates a more realistic situation, whereas more exaggeration creates a more cartoonish action.

This work presented *Viral.izo* 2.0, a casual educational game focused on stimulating initiatives in favour of global health against emerging viral attacks for the management of resources against the rampant proliferation of the virus and its variants, as well as its health hazards. *Viral.izo* achieved player engagement and game competitiveness through the new extensions made in the game: new virus variants with unique visual appearance and behaviour (specific damage powers, spreading speeds and unpredictability), the local ranking system, three new levels of increasing difficulty with customized, very dynamic, and appealing visual effects, and two new minigames. Additionally, we conducted new UX evaluations showing that *Viral.izo* is capable of educating while challenging the player, just in a few minutes of gameplay. The overall average results of the evaluation were very positive.

Nevertheless, many lessons were learnt from the design to the UX Assessment testings of *Viral.izo*. In particular, the participants' insights and suggestions on resolving some game issues will help the development team understand other players and improve the user experience. For example, it was evident that Minigame 1 has a high difficulty level. According to most subjects, the recommendation would be to recalibrate this variable to allow the player to learn more about the chronological order of the main events that deeply marked the pandemic.

In future work, we plan to revise *Viral.izo* according to the calibrations' suggestions made by some of the participants to improve further the quality of the player's experience. In addition, we can implement a virtual shop between game level changes, where the player might invest the earned points to buy health improvements for the antibody cloud, such as increasing its speed and size and even gaining an extra life. In addition, players might use player scores and achievements to purchase skins or other game accessories. Finally, we plan to integrate the *Viral.izo* game with Facebook and use this integration to generate an online ranking through the free PlayFab service, which provides online servers to store game data, such as user information and player scores.

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