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# The Iterative Development of an Online Multiplayer Escape Room Game for Improving Social Interaction through Edutainment

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## ABSTRACT

Digital Games are nowadays used for several purposes beyond entertainment. Such purposes include but are not limited to education, promoting cultural heritage, and improving well-being aspects. A rich body of literature presents experimental studies, investigating whether a serious game achieves its aim. However, most of such papers often omit to provide adequate information on the development process followed, game mechanisms and techniques used, making the reproducibility of the game as such, by other researchers, difficult. This results in a lack of knowledge transfer between researchers, who usually must develop applications under investigation by themselves when at the same time industrial gaming companies rarely publicize the technical insights of their work. This paper aims to contribute towards filling this knowledge gap within the scientific community, using as a case study an online, multiplayer, escape room game, which aims to improve social interaction through edutainment. The full process of its development with details for the various components that the game comprises are presented. We are expanding on the functionality of the game and the optimization of the 3D environment and the assets, among other aspects. Results of white and black-box testings taking place at the end of each development cycle showed that the integration of the various components described within the paper led to a robust game.

## Keywords

Serious Games, Multiplayer, Online, Iterative Development, Social Interaction, Edutainment.

## 1 INTRODUCTION

Digital games are usually used for entertainment and have the ability to engage players, thanks to the games' interactive nature [Bal07a]. Games that do not have entertainment as their primary purpose are called serious games, which, among other purposes, are used for education, the promotion of cultural heritage [Tsi19a], the improvement of well-being aspects [Why15a], and even cognitive training [Kat19a]. Serious games could constitute boundary objects [Sta89a], in the sense that serious games can facilitate cooperation between multiple social systems while maintaining a different identity in each one [Ter21a]. This means that a serious game could be used to elicit various outcomes in different cohorts while providing scientific knowledge on intersecting areas of research. The process of developing a robust serious game can be a complex process, as more aspects need to be taken into account [Bra16a]. Especially for mobile devices, physical and technical characteristics need to be considered throughout the whole development process, from the initial planning to the development of the game itself [Bal15a]. This is because mobile devices, compared to desktop ones, bear important physical and technical differences in their display size, processing power, data input methods, and memory space. These considerations and their practical

solutions and implementations in the development process are often overlooked in the scientific publications, even though they could be useful for reproducibility purposes or for new studies by other researchers.
A great amount of the literature on serious games relies on only a brief description of the applications developed and is usually focusing on the experimental part of the study. Technical details about the development that would benefit future researchers are often missing from research papers. The present paper is in line with the work of Symborski, et al. [Sym17a], which describes two serious games that teach the mitigation of cognitive biases and the experiment cycles and playtesting that they conducted. The research elaborates on various design approaches and provides outcomes from the playtesting phases. Likewise, Zilak, Car and Jezic [Zil18a] describe the development of an elementary mathematical virtual classroom prototype based on Oculus Rift and Leap Motion devices and the user evaluations they conducted. A few examples of studies that attempt to offer more technical details [Del21a, Ari14a] elaborate on the rendering methods or the computation algorithms they used, which avail the reproducibility of similar applications.
The aim of this paper is to present the iterative development method that was used for our multiplayer escape room mobile game to facilitate knowledge transfer between researchers, who usually must develop applications under investigation by themselves when at the same time industrial gaming companies rarely publicize the technical insights of their work. Various technical details and specifications for the components that built up the game, including the game mechanics, functionality, and optimizations made are also provided. The purpose of the developed game itself is to improve social interaction through edutainment and to contribute towards filling knowledge gaps regarding game development for social interaction.

# 2 MULTIPLAYER ESCAPE ROOM GAME

## 2.1 Development Method

Iterative development, which breaks the process of developing a software into iterations that contain the whole process (planning, design, development, and testing steps), was chosen as our approach to the development of the game. Specifically, the agile method was mainly followed as it focuses on iterative refinements and incremental improvements to working software, and in our case, a mobile game [Asu11a]. This method was chosen because it provides direct feedback about the improvement of usability and functionality of the game. This development approach is widely used in studies where game tester's feedback is necessary [Ale16a, Bal07a, Ter21a]. The subsection below provides a brief overview of the process that was followed.

### *2.1.1 Development Method Overview*

The first step of the development process was a planning phase, in which the game specifications were decided. Once the type of the game, its platform, target group, aim, setting, and key features were decided, the pre-production phase followed, in which the game scenario and storyline were decided and storyboards were created [Ale16a]. The first prototype of the game was developed and tested, which included the core mechanics of the game (navigation system, interaction with objects, puzzle mechanics, countdown system), with no finished 3D models or textures. When all the core mechanics were internally tested and confirmed to be working according to the required specifications, then the production phase started, where all the assets of the game (3D models, textures, UI elements, sounds, programming scripts) were gathered. The game was developed using the Unity game engine. Then, at the testing phase, a version of the game was tested with either black or white box testing. The testings that were conducted are described in Section 3. After each testing, another iteration of the development process was taking place, for improving and correcting any shortcomings revealed from the testing.

## 2.2 Game Overview and Design

The genre of the game is a 3D multiplayer escape room mobile game. In escape rooms, players are locked in a room, and by exploring the room, finding clues, and solving puzzles, they can find the way to unlock the room and exit. They usually have time limitations and revolve around various themes and narratives [Bak19a]. Escape room applications are common educational tools for heritage sites. For example, the escape room application for the industrial heritage site of Zissimatos textile factory is designed to educate visitors on the production flow of the factory by gathering objects and solving riddles [Gai18a]. Other similar applications, such as "MillSecret" and "Salamis", make use of the escape room gamification approach and AR technology to enhance the in-situ experience of cultural heritage sites by integrating dispersed digital elements throughout the sites [Tzi20a, Kou18a]. Contrary to the AR related applications mentioned, our game takes a Window on World (WoW) Virtual Reality approach, in order to tackle the limitation of having to be at a specific physical location for the experience to play out. Besides, the functionality of escape room games that are founded on AR technology and physical locations is sensitive to alterations of the games' physical components, which are often prone to change because of temporality [Vas19a]. In our game, players are locked in a series of rooms within the virtual representation of

a real castle and are encouraged to communicate and cooperate in order to solve the puzzles and obtain the exit-pass of the castle chambers. Interestingly enough, being virtually transported inside a 3D representation of the castle enables players to safely visit all site locations, even including those restricted in real life for safety reasons.

Another difference with similar escape room games mentioned is that our game was designed to target educational but also social well-being aspects. For the educational aspect, players are able to learn about the architecture of the castle, its significance, and its history through different time periods, among other information. The whole castle and its chambers are used as the playable environment of the game, in order for the players to visit all areas of the castle during gameplay and gain knowledge for all of its parts. For the social aspect, the game has been designed as an online multiplayer game, where the players should communicate through their smartphone's microphone through voice and interact with each other. Some mechanics of the game disallow any team player from taking the lead and solving all the puzzles without help throughout the entire game session. This is a rarely used experience design that makes it necessary for all team players to speak to each other, ask questions and seek clear answers from their teammates, so all of them contribute in solving the puzzles, winning the game, and participating in the learning process. Of course, such an experience design entails that the chances of winning are much higher when the teammates are willing to be respectful and helpful to each other, which could be an additional challenge to the gameplay. Even so, escape room games are found to cultivate a sense of trust and community among strangers while bringing them together through mutual effort [Gai18a], which arguably is one of their most underutilized properties. Therefore, the educational significance of this game is both cultural and prosocial. This combination of multiplayer smartphone system architecture, escape room setting, and digital storytelling is an innovative gamification approach, which, to our knowledge, has yet to be integrated within the context of cultural heritage education. A video demo of the game can be found as supplementary material.

## 2.3 Storyline

The narrative of the game is inspired by the tragedy play named "The Tragedy of Othello, the Moor of Venice" (in short "Othello"), written by William Shakespeare [Sha93a]. The castle of Famagusta is allegedly associated with the famous legend of Othello, as presented in Shakespeare's play, during the British rule in Cyprus. In the game, the players assume the role of detectives, who seek to investigate and solve a mystery that is taking place in the castle. Once the players solve an initial puzzle inside the castle, players are transferred into another dimension and the castle's main entrance gets locked. Without any obvious escape route left, the players are instructed by Othello's ghost to visit all the rooms of the castle and solve puzzles that will help them discover the means to escape.

## 2.4 Environment, 3D Assets and Avatars

### *2.4.1 Environment, Weather Simulation and Lighting*

**Environment**

The environment of the game has been designed with historical and architectural accuracy according to the current state of Othello's Castle which is located in Famagusta in Cyprus. The castle has been 3D modeled based on actual castle plans and reference photos (see Fig.1).

Figure 1: Real photos from the castle (left) and the 3D model created (right).

The model was compared with a 3D laser scan of the castle[1]. 3D scans are not usually used for interactive applications such as games, as they have a massive number of point clouds and segments and they are unnecessarily large and impractical especially for smartphone devices. Even the optimized version of the 3D scan of the castle's structure, includes 3,100,000 polygons and has a size of 346 MB. Instead, the corresponding 3D model, created manually for this game, has 10,000 polygons and a total size of 3.8 MB with more structural details (see Fig.2).

**Weather Simulation**

In addition, weather effects for simulating natural light and weather conditions were added. For this purpose, the "Enviro Lite - Sky and Weather" (version 2.3) plugin was used from the Unity Asset Store. This plugin provides a real-time weather simulation by simulating the sun and moon through direct light. The lights'

[1] http://ephemera.cyi.ac.cy/?q=OthelloTower

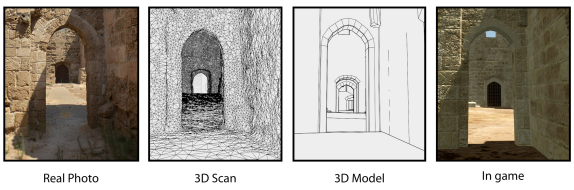



Figure 2: Comparison between the real photo (left), 3D Scan (middle-left), 3D model (middle-right) and in-game result (right).

position, intensity, and color are updated continuously according to the real weather conditions of a specific time and date of the year. Moreover, environmental factors such as fog, dynamic clouds, and stars were added through this plugin.
In the starting area of the game, outside the virtual castle, where players connect, gather, and get familiar with the controls, the weather simulation is happening in real-time. For example, if they start the game on 25 July at 13:00, the sun location and shadows will be according to the real weather conditions on that specific day and time. However, when the players solve the initial introductory puzzle, the game shifts to nighttime for all players, to accommodate the storyline. At the last stage of the game when the players solve the second to last puzzle, a trigger activates rain and lightning effects, which the player can see and listen to through respective sound effects that were added through the same plugin. When the final puzzle is solved, the environment changes to sunrise and players can see more natural light in the environment.

### Lighting

Lighting is another aspect of video games that usually requires a lot of real-time processing power and an aspect that had to be taken into consideration. In our mobile game, one real-time directional light was added, with shadows for the sun/moon movement and one baked directional light without shadows for inside and outside lighting. The torch held by the players, an essential asset that helped resolve the visibility issues of players, was created as a real-time light source and the rest of the lighting was baked in the game. Baking is a pre-calculation of highlights and shadows for a (static) scene, the information of which is then stored in a lightmap. The baked lightmap has been rendered on a second UV map of each 3D model generated by Unity. Baking images were selected to be 2048X2048 pixels in ETC_RGB4 (4 bits/pixel compressed RGB) format for an optimized result in a matter of size and quality.

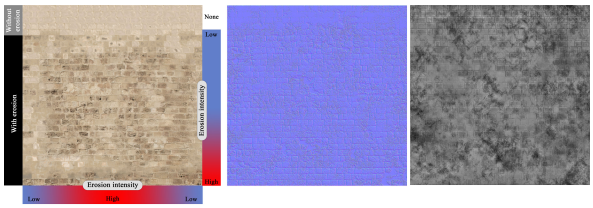
#### *2.4.2 3D Assets and Textures*

### 3D Assets

All the 3D objects inside the castle (e.g. clue items, decorative items, boxes) were created with a low polygon count in order to reduce the rendering process per frame. Additionally, the surrounding environment of the castle consists of low poly models of monuments and greenery for achieving a more realistic experience for the players. One of the main challenges was that it was preferred for the whole game to take place in one scene, which is arguably a non-conventional approach by game development standards. The reasons this approach was chosen, instead of separating each room into a separate scene were: (i) to have one integrated environment where all players can move freely and explore the whole castle, (ii) not loading scenes during run time to avoid delays when moving between rooms and (iii) to preserve the continuity of communications and gameplay.

### Textures

For optimizing the performance, which was a major challenge, only a single texture has been used and applied to the whole castle. The single texture used for the castle is designed to cover the diversity of its erosion surfaces, as illustrated in Figure 3 (left). All the blocks (bricks) have been placed on UV maps to resemble the appearance of the real structure. A normal (Figure 3, middle) and a height map (see Fig.3) were also created, to give the illusion of bumps on the wall's surface.




Base color Normal map Height map

Figure 3: Castle model texture design.

### Avatars

An avatar is the digital representation of a player in games [Now18a]. It allows the players to experience and interact with game objects and other users. In our game, players can choose their own avatar from a list of avatars in the main menu of the game and can see each other's avatars during the game (see Fig.4). According to Trepte and Reinecke [Tre10a] identifying with an avatar can increase media enjoyment and has positive outcomes for the play experience. Additionally, Van Ryn, Apperley, and Clemens [Van18a] mentioned that in multiplayer games, avatars are important for visually communicating with the other players. A different color and a circular halo below the avatar are assigned to each player, so the avatars become more distinguishable among teammates.

Figure 4: Players can see each other's avatars, visually enhancing communication with other players.

## 2.5 Functionality

### *2.5.1 Navigation System*

Players can control their avatars through virtual joysticks on the screen. Virtual joysticks are inspired by their analog counterparts [Kim15a] and are used widely in commercial 3D mobile games like Terraria[2] and Call of Duty Mobile[3]. Two semi-transparent on-screen joysticks with circular knobs, on the left and right side of the screen were added. The left joystick is used for navigation (avatar movement) and the right one for head and body rotation. The player can drag the knobs relatively to the joystick's center to send directional commands.

Moreover, on the right side of the screen, four small circular buttons represent the players' ability to crouch, turn on/off a torch to light up dark spaces, run and jump (see Fig.4). Players can interact with clues and puzzles in the rooms and move boxes around and jump onto them, to reach higher places. During the game, the ghost of Othello appears as a UI image to guide the players. The players can listen to him and read the text in the text box. Also, at the beginning of the game, there are four UI pages of instructions for new users to explain the controls, mechanics, and features of the game (see Fig.5).


Figure 5: One of the instructions pages.

[2] https://terraria.org/
[3] https://www.callofduty.com/

### *2.5.2 Map*

On the top right side of the screen, there is a small circular button with a compass icon, which represents the map. Players can tap on that button to show/hide the map. The map is designed to be world-oriented.These kinds of maps show the entire game world with the north direction at the top, regardless of the orientation of the avatar and the player's perspective [Ada14a]. They are usually hidden from the screen, and players must press a specific button to show/hide it and are usually static.

To implement the map, the exact plan that accurately matches the top view of the 3D model of the castle was used to design a 2D map. The designed map was placed as an image under the 3D model of the castle (in the z-axis). An orthographic camera was placed facing on the image and above the 3D model of the castle. This type of camera was used because it is useful for rendering 2D scenes and UI elements and uses an orthographic projection, in which the object's size in the rendered image stays constant, regardless of its distance from the camera. Moreover, between the 3D model of the castle and the 2D designed image, there are small dots connected to the players' location and colors representing each player's live spatial location in the castle. The camera renders only the map-related layers and no other 3D objects in the scene through the Culling Mask feature of the Camera in Unity. Finally, the rendered image through this camera is projected on a target texture where the players can monitor their and other players' location on the map. For navigation aid purposes, an arrow on the map shows players where their next destination is.

### *2.5.3 Communication and Collaboration*

It is important to note that there is no competition between the players. Striving toward a common goal could reduce subgroup categorization and transform the "us" versus "them" perception into a more inclusive "we" [Gae00a, Has13a]. One of the main challenges was to find a proper way to maximize and encourage cooperation, interaction, and communication between the players. The challenge was addressed by enabling or disabling the visibility of different key objects to the players, depending on their current role. In each room, one player is randomly chosen as a "solver" who can only view and solve the puzzle but not the related clues, whilst the rest of the players (named as "helpers") can view and have access only to the clues but not to the puzzle.

To ensure that all the players will be selected as a "solver" during the game, the following algorithm was used. Two lists of players are created at the beginning of the game. List A which is the list of all the connected online players at the moment and List B is the list of all the players who didn't play as a "solver" yet.

List B is empty at the beginning. The players in the game, before reaching each room, collide with a trigger for the selection process. As soon as one player activates the trigger, all the players will update List A and List B but only the master player (who hosts the game and is selected automatically through the "Photon Unity Networking (PUN 2)" plugin) will select a random number to indicate the "solver" ID. The result will be shared with all the players through the network. The selected player will be removed from List B. Then, each device will check if the current player ID is equal to the "solver" ID and will take action accordingly. The clues will be deactivated and the puzzle of this specific room will be activated for the "solver" and the opposite for the "helpers". When the puzzle is solved, the clues and puzzle(s) of that room become visible to all players and available for further interaction. Also, if any player leaves or disconnects from the game, the selection process is repeated to avoid losing the "solver" so that the remaining players do not get "stuck" in the game. The flowchart of the "solver selection" algorithm is provided in the supplementary materials.
By implementing this mechanism in the game, cooperation and direct communication between all players become necessary and thus the voice chat feature was added as a convenient communication method. The voice was integrated into the game through the "Photon Voice 2" plugin.

## 2.6 Rooms, Puzzles, and Clues

### *2.6.1 Rooms*

The castle consists of 6 main rooms which are originally locked. Each room is dedicated to a specific topic relating to the castle. The rooms and their respective topics pertain to Historical periods, Castle visual information, Construction characteristics, Castle's architecture changes, Music knowledge, and the Shakespearean tragedy of Othello. As the game's storyline follows a linear path, the players enter the rooms in a predefined order. For the players to move to the next location, they are encouraged to communicate and collaborate in order to find the clues and solve the puzzle(s). Players have 90 minutes in total to finish the game, with a chance of gaining extra time by collecting time bonus figurines hidden in areas inside the castle.

### *2.6.2 Puzzles and Clues*

For the puzzle mechanics, the object interaction, the narration trigger, and the main UI menu, the "First person narrative adventures + complete puzzle engine" plugin (version 1.1.2) was used from the Unity Asset Store. The plugin was designed for a first-person view offline game without avatars. The network variables and rules in order to have synchronized changes and motions in the game for all network players were added.

**Puzzles**

As mentioned above, once the players enter a new room, one of them is assigned as a "solver", who is the only one that can see and interact with the puzzle (see Fig.6). In order to interact with the puzzle, the "solver" must come to close proximity to it. When they do, a small circular puzzle piece icon appears on the puzzle itself, on which the player can tap. After that, the camera zooms in and gets fixed on the puzzle, so that it is in their front view, and then they can interact and solve it, with the help of the "helpers". The "solver" has the option to reset or exit the puzzle view at any time. "Helpers", in order to collect clues needed in solving the puzzle, can interact with some objects in the room as well and explore them in a 3D view mode.


Figure 6: One of the puzzles regarding the construction characteristics of the castle.

The puzzles in the game come in four different forms which are described below (see Fig.7). Logic puzzle: In this type of puzzle, the player must drag and drop some items in their correct place (see Fig.7, A). In the game, several logic puzzles are used in different formats and designs. Some of the items can be photos of areas of the castle, coins, or parts of the castle map which must be placed in the correct order. For example, in the telescope puzzle (see Fig.7, F) the players try to find the correct combination and order of lenses in a telescope and look through it to get the correct keyword.
Lever puzzle: In this type of puzzle, the player must find the correct set of lever positions. A green light indicates their correct position (see Fig.7, B). Also, each puzzle can include several levers that are related to each other, which adds some complexity to it.
Sliding puzzle: In this type of puzzle, there is a board with a picture that is split into several blocks (e.g. 3X3) and a missing block (see Fig.7, C). The player can tap on a block next to the empty place and replace that block's position. The player must find the correct pattern to form the picture by moving the blocks.
Rotary puzzle: The mechanics of this puzzle are similar to the lever puzzle. The player must find the correct position of each part, to form a number code or a word,

but the rotation of the parts is happening vertically (see Fig.7, D) or horizontally (see Fig.7, E). Each part can include 3 to 10 steps.

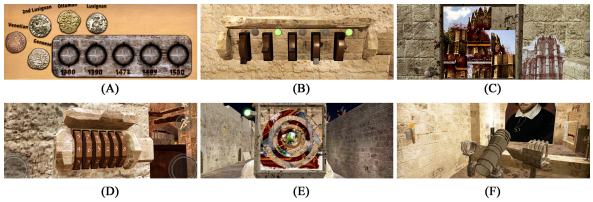



Figure 7: Examples of logic (A), lever (B), sliding (C), horizontal rotary (D), vertical rotary (E), and telescope (F) puzzles in the game.

**Clues**

When the "helpers" are close to a clue, a circular icon appears on it, which players can tap on and interact with. Some examples of the type of clues that exist in the game are writings on the walls, banners, boards, or books with information.

## 2.7 Software

The game was developed for Android devices in the Unity software (version 2020.2.0f1) and the programming language C#. The Photon Unity Networking (PUN 2) plugin (version 2.4) was used for the multiplayer features of the game and the Photon Voice 2 (version 2.29) for the voice chat. The open-source software Blender (version 2.9) was used for the modeling, 3D designs, and UV mapping of the castle reconstruction and all the items within it. The UI elements and textures were created in Adobe Photoshop (version 22.5.4), Studio Clip Paint Pro, and Blender.

# 3 TESTINGS

The whole development process of the application was completed in four more iterations, in addition to the prototype created. The first two iterations used white box testing, with the testers being people who knew the internal structure of the game. The rest of the testing was carried out by black-box testing, with external testers. Throughout testing, the various aspects of the game, like the core game mechanics, the network features, the game structure, and the user experience of the game were evaluated (see Table.1).

| | Iteration | | | | |
|---|---|---|---|---|---|
| | White-Box testing | | Black-Box testing | | |
| **Game aspect tested (focus)** | **Prototype** | **Iteration 1** | **Iteration 2** | **Iteration 3** | **Iteration 4** |
| Core mechanics | medium | low | | | |
| Mechanics integrated in the game | | high | high | low | low |
| Networking | medium | medium | high | low | low |
| Game structure | | | | medium | medium |
| User experience | | | | high | high |

Table 1: Distribution of the game aspects tested in each iteration and their focus.

## 3.1 Instruments and Procedure

### *3.1.1 Instruments*

For the black box testing, the questionnaire used included questions regarding the game structure and user experience. The game structure questions were about the puzzle(s) in each room, such as questions about the difficulty of finding the location and clues of the puzzle and included a 5-point Likert scale and an open-ended question, where testers were encouraged to evaluate the puzzles.

The user experience questions included 5-point Likert scale questions relating to the game's visuals, how easy it was to follow the narrative, map usability, and communication with other players. It also included usability questions regarding the avatar selection procedure and navigation. Moreover, open-ended questions were added, where testers could mention if it was clear to them who the solver and helpers were in each room, what aspects could be improved, and what were their favorite and least favorite aspects of the game.

### *3.1.2 Procedure*

Game testers were invited to participate by email invitations that were sent internally and on posts on social media. People could express their interest, their availability and contact the researchers in order to arrange sessions of preferably four people. They were given the link to download and install the game on their mobile device in advance. Sessions could take place remotely or physically in a lab setting. All testers, with the exception of one person in the last iteration, were physically present in the lab during testing.

At the beginning of each testing session, testers were briefed about the premise of the game and that they could communicate with each other through the microphone of their device. They were also informed that, after completing each room's puzzle(s), they would need to complete the corresponding questionnaires. The testers could be either in a separate physical space or the same room, where they could communicate through their devices or face to face but were prohibited from seeing each other's device screen. The problems and difficulties testers were experiencing during testing were observed and written down by the researchers. At the end, when the testers either finished the game or quit, they were asked to complete the user experience part of the questionnaire.

### 3.2 Prototype

Game prototyping helps developers to check the core mechanics of the game [Ale16a]. During the pre-production phase, a prototype of the game was created, which included the core mechanics of the game with no final models or textures. These core mechanics include the navigation system of the game, the interaction of players with objects and the puzzles, the countdown, the mechanics of the puzzles (logic, lever, sliding, rotary), and the networking feature. White box testing took place with the development team, who knew the internal structure of the game, to test these core mechanics and the networking feature.

### 3.3 Iteration 1

After the core mechanics and the networking features were tested and working as intended, they were integrated into the game with the rest of the created 3D models. White box testing facilitated the integration of the networking features, the core mechanics, and their applicability in the environment of the game.
Several technical conflicts and bugs were recognized and resolved, mainly regarding network parameters, shared or synchronized objects in the network.

### 3.4 Iteration 2

For iterations 2 through 4, black box testing was used. After the core mechanics and networking were integrated and working correctly, the researchers proceeded to test mainly the game structure (rooms and puzzles) and user experience of the game.
Two groups, one of four people and the other of three, tested the game from different locations. None of the groups managed to complete the game. During these tests, problems in voice communication and some synchronized objects for the network players were observed and resolved. Also, game instructions were added to the game after this iteration.

### 3.5 Iteration 3

In the third iteration, three groups of game testers played through the game. The first two groups consisted of two players and the last group of three players. Two of the groups managed to reach the Construction characteristics room (third room) while the other group managed to reach the Music knowledge room (fifth room). Using the feedback from the testers using the questionnaire and the observations made from the researchers, the changes that were made in the application during the first iteration were:

- The Castle visual information and Historical periods rooms were swapped because according to the testing results, the Historical periods room was rated as easier in terms of its puzzle difficulty for the testers. An incremental difficulty escalation was achieved by posing the easiest challenge first.
- More player guidance was added in the Historical periods room to clarify that only one person can see the puzzle and the rest can only see the clues.
- The navigation system on the screen was updated by adding a new joystick on the right side of the screen for the player's head movement (rotation).
- The communication system (voice chat) was improved since technical issues were observed.
- More lighting was added to the environment as users expressed complaints about the visibility in the game.

### 3.6 Iteration 4

In the fourth iteration, three groups (the first two groups consisted of three players and the last group had four people but one of them left the game before the game finished) played through the game. All teams managed to finish the game. The first team finished it in less than 90 (80min 12 sec) minutes and the second team in less than 120 (116 min 20 sec) minutes and the third team less than 100 minutes (96 min 23 sec), after gaining extra time, by collecting time bonus figurines. The recorded time includes answering the questionnaire as well. Recommendations led to multiple changes:

- Lighting was improved by some adjustments and the player's torch, which was turned on at the beginning of the game, was turned off.
- The number of moving obstacles on the roof after the completion of the Music knowledge room was reduced to balance the difficulty.
- Improvements to the navigation system (jumping power was increased and the sensitivity of the right joystick/head movement was reduced).
- Adding a skip button for the narrations in the game.
- Adding invisible colliders in corners so that players do not get accidentally stuck and more invisible colliders in some walls because some clues were mistakenly accessible from other rooms.

These final changes were implemented in the game, which led to the final version of the game.

## 4 DISCUSSION AND CONCLUSIONS

The iterative development process of a multiplayer escape room mobile game was presented. The paper described the technical implementations that were integrated into the game, the weather simulation, the baked lightmaps, the single texture used for the 3D model of the castle, the map, the selection algorithm for the "solver" in the rooms and the puzzle mechanics. Game

testers, through the use of questionnaires and observations, evaluated the game's functionality and user experience. The iterative design approach revealed persisting issues relevant to the navigation, difficulty scaling, player guidance, and lighting of the game. These issues were identified and resolved with the use of iterative cycles, which helped in incrementally improving the quality of the experience and the game as a whole.
As seen from the results, in the fourth and last iteration of the game, all groups managed to finish the game and their feedback consisted of simple refinements and bug fixes. The initial target of social well-being was achieved, as all the testers found their communication with the other players in this game to be efficient. Additionally, most of the testers emphasized that their favorite parts of the game were the communication and cooperation part, as well as the puzzles. The game itself was found entertaining to play and visually appealing.
The outcomes of this iterative design approach are comparable to the outcomes of similar works on escape room games for socialization and learning, with an example being the escape-room game AScapeD [Ter21a]. A fun and challenging experience was achieved while maintaining equality in the cooperation among players. One of the strongest characteristics that the present game and AScapeD share is the emphasis on turn-taking and the equal contribution of every member of the team in achieving their common goal [Ter21a]. Another example is the work of Thurner-Irmler and Menner [Thu20a], where their twice-tested escape room was accepted by their target group as an interesting way of knowledge transfer.
It is envisioned that the capabilities of the presented game, as a boundary object, will be best utilized towards improving interpersonal and inter-communal relationships. The presented game has the potential of conveying the importance of preserving cultural heritage and the value of cooperation among individuals and communities. These messages lie at the core of the game design and are integrated into both the narrative and the more technical aspects, such as the game mechanics and the 3D models.

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