

Designing an AR-Escape-Room with Competitive and Cooperative Mode

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Abstract: Live Escape Rooms have become very popular in recent years. Solving riddles and puzzles in teams to open locks and doors is a great gaming and also social experience. We transferred this concept into an Augmented Reality (AR) game. This way it is location-independent. The game can be played in a competitive and cooperative mode. We performed a study with 33 participants to explore how the augmented version is received in comparison to other Escape games. Furthermore we investigated the impact of the different modes on the player's gaming experience.

Keywords: Augmented Reality, Escape Room, AR Games, Multiplayer, Cooperative Mode, Competitive Mode

1 Introduction

Escape Rooms were invented in 2007 and became quite famous during the last decade. They are testing the players' wits and riddle solving skills while evoking competition that is a basic reason for people to play games [Nic15]. On this occasion a team with several players has to solve challenges in a usually closed room in a limited time. These challenges are usually puzzles or search games. Solving them yields rewards and enables the access to more hints, puzzles or other rooms until the game is solved and the final door opens [WEC15]. Fun is on high priority but it has also a social component, because the tasks are strengthening the cohesiveness in the group. Therefore, these Escape Rooms are also used as team building exercise. This paper will showcase 'AR-Escape', an Escape the Room game with AR implemented for multiplayer that can be played in cooperative but also in competitive mode. We conducted a study with 33 participants to explore the following research questions:

- Is AR-Escape a suitable alternative for Live Escape Games?
- What is the impact of competitive and cooperative modes on user's gaming experience in AR-Escape?

2 Related Work

Due to the popularity of Escape Rooms, many variations have been designed, like tabletop games, video games or video games using VR. We will at first have a deeper look at these different alternatives:

- **Tabletop Games** can be played at home in small groups. They include some printed sheets and simple gadgets. Therefore, no complex interactions are possible. 'EXIT - The Game'-series [Bra17] is a typical example. These kinds of games are well designed and also location-independent, but they can only be played once and all players have to be at the same place.
- **Video Games** include more complex puzzles, as they do not suffer from physical limitations. Impressive worlds with free movement can be implemented. Unfortunately, the multiplayer aspect suffers, as each player sits alone behind their gaming device and can only communicate with voice chat. In 'We Were Here' [Gam17] two players are locked in different locations and have to solve puzzles by communicating. The game does not include a timer, as the game takes several hours to finish.
- **VR Games:** There is also a version of 'We Were Here' [Gam17] using VR. In this case, only head movement is included, because the games are not primarily designed for VR. 'Huxley' [VR7] is a licensed game for professional Escape Room services. It is played with up to four people, who all use a VR device during the game. They can see each other in the virtual world and play an Escape Room purely in VR. Of course, haptics is still an issue in VR [Q⁺20] and also collaboration is often based on one-to-one respectively local user and remote expert [L⁺20].

AR is already used in a plethora of games in the entertainment sector but there are also Serious Game that use it [TS10]. So called Serious-AR-Games are transferring knowledge to the player. Examples in the field of immaterial cultural heritage are 'Oppidum' [PEKK19] which teaches information about the life and history of the Celts or 'Dragon Tale' [PEK⁺18] which is about Japanese Kanji. Another examples were AR Scratch [RM09] and ARQuest [GV19] that introduce programming skills to children. The impact of collaborative and competitive modes in a multiplayer game have also been analyzed by Siu et al. [SZR14].

3 Game Design

The game was developed using the Unity cross-platform game engine and the AR content is handled using the Vuforia Engine. The communication of the different devices among each other and with the server is managed by Ubi-Interact [WK20].

3.1 Requirements

In order to play the game, the user has to install the game on an Android device. After all markers are printed and distributed over a table (See figure 1), the game is ready to start. Additionally, when the game is played in multiplayer mode, the different devices must establish a connection to the server.

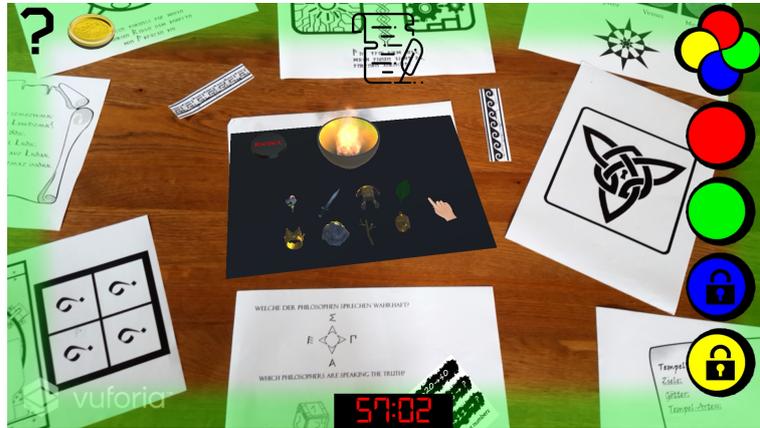


Figure 1: Example setup of the game with augmented markers

3.2 Usage of AR in the Game

We selected categories and compared different versions of Escape Rooms according to these (see table 1). Overall, AR is cheaper and easier to use for private users, because it can be set up fast and only needs a smartphone to play. However, AR also has some specific disadvantages. These include the dependence on certain lighting conditions and the fact that the smartphone or tablet, which of course must meet certain technical requirements, must be held in the hand for the entire duration of the game.

Escape the Room versions					
	Real Life	Board Game	Video Game	VR	AR
Location independent		X	X		X
Dynamic player count	X	X			X
Cost efficient	X	X			X
Can be set up fast		X	X	X	X
Complex Interactions	X		X	X	X

Table 1: Comparison between versions of Escape Rooms.

3.3 Gameplay

The Game can be played anywhere: The markers have to be printed on sheets of paper and distributed on a table or in a room. The game is installed on a handheld device (smartphone

or tablet). After starting the game, the device's camera has to be used to track images. Augmented objects appear on the screen which can be used for interaction. At first, only few puzzles can be accessed, the others are locked by a filtering system. Each filter has a specific color, which illustrates the relationship to the corresponding puzzle. They can be unlocked by unraveling the puzzles. The game has to be solved in less than one hour. Depending on the user skill, it takes usually about 50 minutes to finish it.



Figure 2: Riddles locked behind yellow and blue filter.

3.4 Structure

The game is structured linearly, challenges have to be solved to unlock more. In order to separate them, filters were implemented. When a marker is not available yet, a colored noise is rendered instead of the AR object. This leads to a more linear and clearer gameplay.

3.5 Shop-System

Additionally for solving puzzles, users gain gold which can be used to buy hints or other bonuses. Escape Rooms are played by a high variety of people with different skill sets and education backgrounds. In order to make the game accessible to as many players as possible, it contains ways to help, if someone is stuck. Classical Escape Rooms solve this by having a guide who supports the players. In AR-Escape the Room, the players can buy these hints to solve puzzles or unlock the next filter in the shop system. This adds an additional strategic layer, as the players have to decide how to invest their amount of money. In the competitive mode, the gold can additionally be used to buy sabotages, like disabling the opponent's device for some seconds.

3.6 Puzzles

The puzzles can be separated into two categories: Interactive and non-interactive puzzles. Non-Interactive puzzles do not contain any direct interaction. While the device is used to augment markers to see challenges, it is not needed to directly solve them. Instead, the users have to think and solve them in a more 'classical' way, i.e. thinking about the solution

and make some notes on a piece of paper. AR is used to hide them behind filters in order to not show them to the players. These are mostly 2D objects rendered in front of the marker. An example of this puzzle is a number sequences, where the user has to deduct the next number (see figure 3). In interactive puzzles, the player has to master the challenge

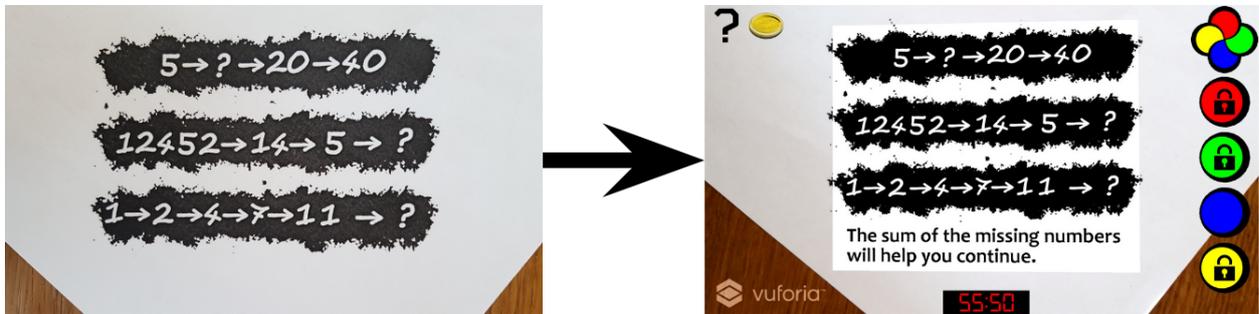


Figure 3: Example of a simple 2D marker

by directly interacting with the augmented objects on the device. These can be mechanical puzzles in which the user has to press objects in the right order or view them from different perspectives to find a solution. When solved, rewards yield solutions to unlock new filters or influence other puzzles to advance the game. In the 'Bulb Puzzle' (see figure 4), several light bulbs are presented. When one is pressed, it and its neighbours toggle their light. To solve this puzzle, all bulbs have to shine. The 'Portal Puzzle' (see figure 5) contains a 3D object which acts as a window to space. Depending on the angle from which the device is held over the marker, the user can see different stars which form numbers. Finding the correct star constellations will lead to the solution. This puzzle would be very hard to implement without the help of AR, as the spatial relation between the tablet and the target are crucial to this setup.

3.7 Tangibles

The game also contains tangible real-world objects which serve as additional markers. These are either objects with 2D markers on them, or the whole tangible itself serves as a 3D marker. Their main purpose is to add more variety, as the game only has printed sheets as trackers where the interaction only takes place on the device. As these objects cannot be printed easily, unless the user possesses a 3D-printer, these puzzles are optional. They are not needed to win the game, but yield additional rewards, i.e. gold. In the 'Pyramid Puzzle' (see figure 6), a small number of wooden pieces are used to build the pyramid. On the outer sides of the pieces, markers are attached. When the complete object is targeted by the device, the puzzle will be finished and the users gain their rewards. In the 'Statue Puzzle', four 3D-printed statues of Roman gods have to be put on 2D planets of the same name. The device then tracks the statues and checks if they are positioned in the correct order.

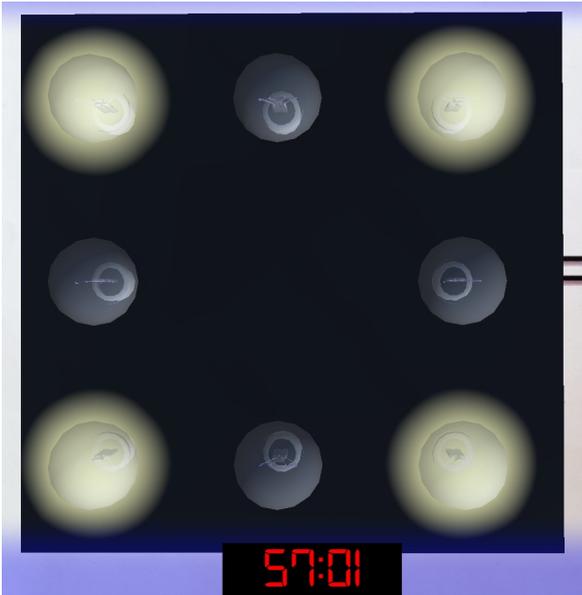


Figure 4: Make them all light up. Pressing on a lamp changes its state and that of the adjacent lamps.

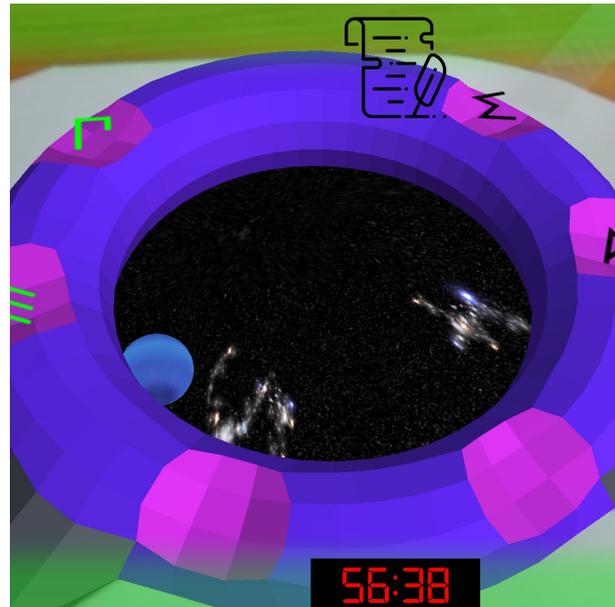


Figure 5: View into the virtual portal into space to discover the numbers formed by stars

3.8 Multiplayer

Escape Rooms are usually played in teams. Sharing only one device for three people or more can be tedious and reduce the overall game play experience. To counter this, more devices that are connected on a local server were added. With the addition of network connectivity, two different game modes were implemented: Cooperative and competitive. In the cooperative mode, up to four players are locked in one room. They use two connected devices. They have one hour to finish the game. The state of all puzzles as well as other important data is synchronized between them. In the competitive mode, two teams have to compete against each other. There is no time, instead the team that escapes, i.e. solves all puzzles first, wins. Another difference is the added options in the shop to invest money to sabotage the enemy team (see section 3.5). In this mode, the teams can be in different locations, as they only need to connect to the same server. The game is designed to use two tablets per team. The maximum number of tablets that can be used is eight in total

4 User Study

4.1 Questionnaire

A questionnaire was designed for each mode to tackle the mentioned research questions (see section 1). Both contain:

- Personal Questions
- Experience in AR, VR, Tabletop, and video games

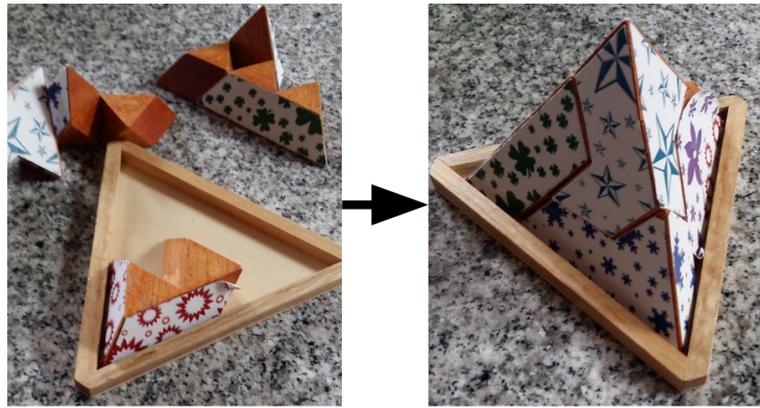


Figure 6: Pyramid puzzle

- Which kind of Escape Rooms are preferred (AR, VR,...)
- Enjoyment of all interactive puzzles and non-interactive puzzles
- Social Questions taken from the 'Game Experience Questionnaire' (GEQ) [IDKP13]

Questions can be either statements asking how much the user agrees from 0 (not at all) to 4 (absolutely) or free questions asking for more details. The cooperative questionnaire contains some additional questions about how playing as a team with two devices is reviewed, and the competitive one some about whether the game is more stressful and whether the shop is used.

4.2 Results Cooperative

In the cooperative version, 17 persons took part. Seven were students, the others were volunteers. 35% were female and 65% were male. The average age of all testers was 26.70 with a standard deviation of 9.11. The team sizes ranged from two to four people. Each team had two tablets connected to a local server. The average play time per user was 54 minutes, with a standard deviation of 10.37. All teams were able to win the game. The size of the team did not have any impact on the time to finish the game. Several questions were used to find out how AR compares to other versions of Escape Rooms. When asked how experienced the users were, the average experiences were 1.41 for AR, 1.53 for VR and 1.35 for Escape Rooms, which are between slightly and moderately. They felt moderately (2.35) experienced with tabletop games, and fairly (3.35) experienced with video games. The average rating of liking Games using AR was 2.47, and the testers agreement whether AR enhanced the game was positive (2.82). They only slightly (0.88) preferred the game without AR. While the testers felt AR was enhancing, they would still moderately (2.12) prefer a real Escape Room. Overall, while AR was positively rated, real Escape Rooms are still preferred.

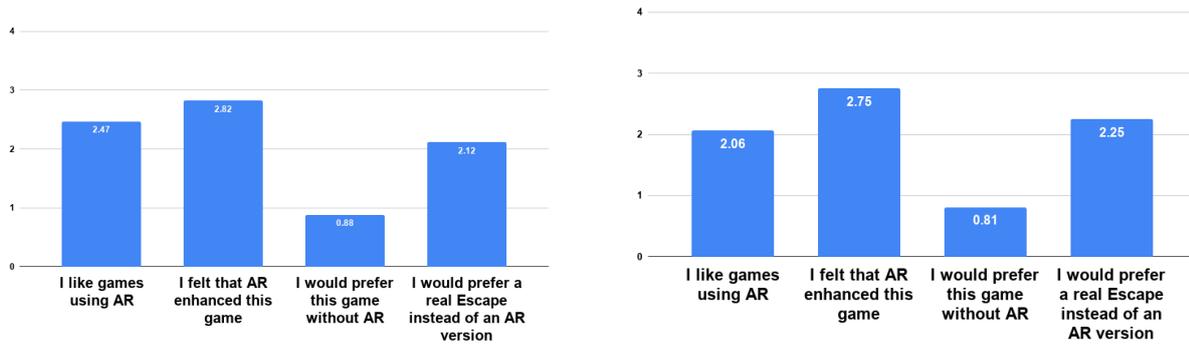


Figure 7: AR enjoyment in cooperative (left) and competitive mode (right)

4.3 Results Competitive

In the competitive mode, 16 other people took part. All were students. 68.75% were male, 18.75% female, and 12.5% divers. The average age was 19.38, with a standard deviation of 0.81. The game ended, when one of the two competing teams won. The average time until the match finished per player was 61.25 with a standard deviation of 19.45. The users overall were slightly experienced with AR (1.06), VR (1.06) and Escape Rooms (1.25). They were more experienced with tabletop games (2.44) and very experienced in video games (3.31). They moderately liked Games with AR (2.06), felt that it enhanced the game (2.75), and would only slightly prefer this game without AR (0.81). They would moderately prefer a real Escape Room instead of AR (2.25).

4.4 Comparison

Playtime Competitive matches on average were longer. The average playtime for cooperative was 54 minutes and 61.56 minutes for competitive, with a difference of about seven and a half minutes. This does not include the times of the losing teams in competitive, therefore the average time to finish would be even longer. Also, cooperative teams solved the optional tangibles, while most competitive players ignored them. If they had not used them, they might have finished the game even faster. It was expected for competitive teams to finish the game in a shorter amount of time. The increased stress and the lack of a clear time frame could be possible reasons for this phenomenon.

Game Enjoyment While overall the enjoyment of competitive and cooperative games was mostly similar, with only small deviations in some questions, there was a high variance in the Competitive questionnaire's answers. Users, that belonged to the losing teams gave lower ratings overall. For example, when asked whether playing against another team made the game better, the winners averaged 3 and the losers only 1.25, leading to a significant ($p=0.01$) difference of 1.75. Nonetheless, when combining the ratings of the winners with those of the losers, the average is similar to the cooperative players.

Social Component The Social Component from the GEQ contains 17 questions that research negative feelings, empathy and behavioral involvement. There was mostly no statistical significant difference in those components, except for two specific questions:

- I felt revengeful
- I felt schadenfreude (malicious delight)

The cooperative players rated almost zero on revengeful and zero on schadenfreude, while the competitive players (mostly the winning players) rated those much higher (see figure 8). The main reason for the increased negative feelings was likely the thrill of winning the game as well as the sabotage system. Winning teams prefer to use the sabotages to tease their enemies.

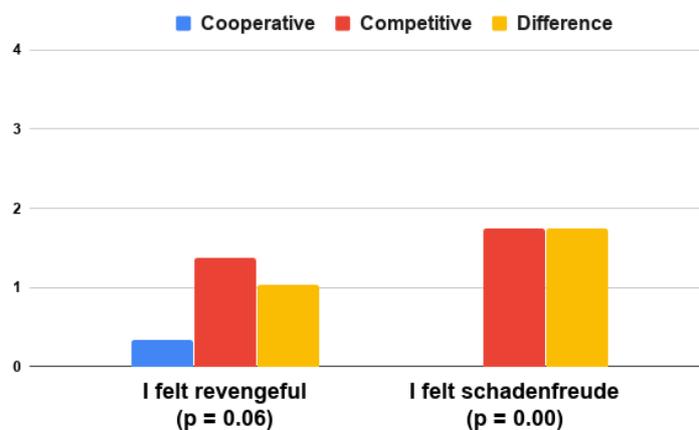


Figure 8: Difference on negative feelings

Tangible Usage The tangible objects were used less in the competitive games. Most players did not use them, despite the promise of additional gold to gain an advantage. Instead, the players wanted to solve the mandatory puzzles as fast as possible to win the game. To ensure, that they try the optional challenges, the rewards might have to be increased, as well as add other forms of motivation.

5 Conclusion

5.1 AR in Escape Rooms

The research proofed AR-Escape to be a suitable alternative for tabletop or digital Escape Games. It can be played at any location with adequate lighting. The game is set up very quickly and yet it contains complex puzzles. As classical Escape Rooms, AR versions can be played alone as well as in teams. As the main game features are on the device, they can be customized to the users, e.g. the language. Too many 2D markers can become tiresome.

Comparison of Cooperative and Competitive	
Average playtime	Significantly ($p=0.08$) longer for competitive teams. Reasons might be more stress or lack of a timer.
Game enjoyment	On average the same for both modes, with higher variance in the competitive team between winning and losing players.
Social component	Significant differences on negative feelings revengeful and schadenfreude (see figure 8).
Tangibles	Used less in the competitive mode. Players were not motivated to invest their time on optional puzzles.

Table 2: Differences between game modes

The addition of real-world tangibles was highly rated by many users. They liked to have something to actually touch while still being able to easily verify it with the device to get the rewards. Most testers would still prefer real Escape Rooms. While the AR was very liked, holding and using a tablet for more than one hour was tedious for some users.

AR-Escape compared to other variants of Escape Rooms:

- Like tabletop games it can be played anywhere with the usage of tangibles
- Like video games, it has complex virtual puzzles.
- Like classical Escape Rooms, it can be played in a team.
- Like VR games, it includes free player movement.

5.2 Multiplayer

When considering the impact of competitive and cooperative modes on the user’s gaming experience, the most important difference is the behaviour of the players and the perceived feelings. The competitive mode felt more stressful, which may have led to needing more time to solve the puzzles as well as ignoring the optional tangible puzzles. Winning players enjoyed the game more than losing players, but the average enjoyment was the same as in the cooperative game. Both game modes received positive feedback. In the cooperative mode, two devices were used per team, which highly increased the gameplay quality, as the users could more freely switch their devices instead of everyone looking at one screen simultaneously. Both game modes were rated positive. Both testing groups were independent yet rated most aspects, like enjoyment of puzzles, quite similar. Some users in the competitive mode claimed that despite the game feeling more stressful, winning felt very enjoyable.

6 Future Work

6.1 User Study

Thirty-three persons tested the game. There were significant differences in age distributions (Coop: 26.70, Comp: 19.38, $p = 0.00$) between both groups. A more homogeneous group

for both game modes might yield other results, as well as more testers overall.

6.2 Changes to Multiplayer

Cooperative Changes Cooperative mode has been regarded quite positive, adding another device for each team was highly appreciated. Both devices had the same configuration and set of puzzles. They could be split for both devices, giving them different tasks. In earlier versions of the game, it was tried to separate the teams in two isolated rooms with few communications possible. The goal was to enforce teamplay by separating some puzzles and information. Splitting the team in different locations might be a possible variation in the future.

Competitive Changes The competitive mode has been proven as an interesting alternative and has many possibilities for future work. At the moment, there are not much competitive features. More possible interactions between teams can be added. For example, have teams directly compete in some puzzles, or add small competitions like solving a math problem first. The team that wins first receives more gold or gets another advantage. So far, this game has only been played with two teams. More teams could be added, to see how the dynamic and behavior of the players might change.

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