

Maze Commander: A Collaborative Asynchronous Game Using the Oculus Rift & the Sifteo Cubes

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ABSTRACT

In this paper we present Maze Commander, a two-player game using two different types of interaction. One player uses the Oculus Rift and the other uses the Sifteo Cubes. The game requires effective and efficient communication to win the game. We also conducted an evaluation. The results show a positive evaluation for the game experience and collaboration, but no significant differences in game experience between the two modes of interaction. However, preferred interaction modalities were not yet taken into consideration for selecting the participants. We also present lessons learned from this experiment, and our future work.

Author Keywords

Collaborative; Game; Oculus Rift; Sifteo Cubes; User Experiment; Game Experience

ACM Classification Keywords

K.8.0 General: Games; H.5.2 User Interfaces: Input devices and strategies, Evaluation; K.3.1 Computer Uses in Education: Collaborative learning

INTRODUCTION

Novel modes of human-computer interaction supported by novel controllers have appeared in the last years, the most well known being the gesture-based interaction supported by controllers such as the Microsoft Kinect¹ and the Nintendo Wii². These new modes of interaction and associated controllers are also used in games, regardless of whether they are used for fun or for serious purposes. However, little is known about the effect of the interaction mode or controller on the player experience and performance. Having this information would not only allow choosing the most appropriate mode of interaction for a particular game, but could also be interesting in the context of serious games to increase the intended outcome.

¹<http://www.microsoft.com/en-us/kinectforwindows/>

²<http://www.nintendo.com/wii>

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The purpose of this work is to investigate whether the choice of interaction mode/controller has an impact on the game experience, in particular for two novel and less research controllers. For this reason, we developed a two-player game, Maze Commander³. This game aims fostering communication and uses two novel interaction modalities, the virtual reality glasses of Oculus Rift [23] and a tangible interaction mode using Sifteo Cubes [19] [18]. Each player is using a different mode of interaction to play the game. Maze commander can be considered as a serious game since it promotes 21st century skills [7] such as communication and collaborative work. However, in the context of this paper, we do not focus on the effects of the interaction modes on improving communication and collaboration skills. We rather focus on effect on the game experience and collaboration. We first investigated whether the choice of interaction mode/controller has an impact on the game experience, as a good game experience is an important factor for a serious game. Without a good game experience, a serious game will not be successful.

We describe the game, as well as an experiment done to investigate whether the mode of interaction has an impact on the game experience. A positive evaluation was obtained for the game experience and collaboration, but we did not find significant differences in game experience between the two modes of interaction. We also formulate design recommendations based on the formative within-subject evaluation.

The rest of the paper is organized as follows. First, we provide background information about the collaborative games. Next, we discuss related work. Then, we present Maze Commander and subsequently the experiment performed and the results. This is followed by discussion and future work, and conclusions.

BACKGROUND

Collaborative serious games [32] are used for specific purposes such as team building, learning effective communication, and practicing collaborative tasks. In collaborative games players work together on shared tasks to achieve common goals [1], thus, in the context of serious games the term “work together” can have different meanings depending on the learning objectives of the game. In [1], three main groups of collaborative games are identified: Instructional collaboration in which collaboration is purely based on the instincts

³<https://www.youtube.com/watch?v=55TaHKHgFDU>

of the players, Supportive collaboration in which the players have the time and opportunity to discuss and strategise at a conscious cognitive level before the game commences; and Integrative collaboration that provides the context of making collaborative decisions while playing the game. Most digital sports games, such as FIFA⁴ fall into the second category and games such as TeamUp⁵ fall into the third. The game Maze Commander falls in between the second and third category.

There are numerous examples of successful collaborative games, starting from board games, e.g., Ghost Stories⁶ to digital games, e.g., Portal⁷ and more specifically serious games, e.g., Escape From Wilson Island [31]. However, to the best of our knowledge the mode of interaction with most of these games is the same for all the players whether they are physically in the same location or not.

Several attempts have been made in the literature to identify the building blocks and the essential components of collaborative games. In [32], the authors provide a series of guidelines for designing collaborative games based on an analysis of collaborative board games. On similar grounds, in [33] a series of guidelines for designing collaborative educational video games are provided by taking the cooperative working requirements introduced by Johnson & Johnson in [13] as starting point. Viktor Wendel et al. [31] combined the two sets of guidelines and augmented them with their own finding. This resulted into nine components that can be used in the design of collaborative games: Common goal/success, Heterogeneous resources, Refillable personal resources, Collectable and tradable resources, Collaborative task, Communication, In-game help system, Scoreboard, and Trading system. These components cover almost all the building blocks that can be found in collaborative games. Based on the purpose of a collaborative game, certain components from this list can be deployed in the design process. For the Maze Commander game, four components were deployed. We discuss them in the design section.

RELATED WORK

First, we discuss related collaborative serious games. Secondly, work related to collaborative games with the Sifteo Cubes is considered and thirdly, work related to games with the Oculus Rift that have the potential to be collaborative is discussed. To our knowledge, no work combining the Oculus Rift and the Sifteo Cubes exists. Finally, we discuss work that investigates the impact of different interaction modes or controllers on the game experience.

Collaborative serious games

To begin with collaborative serious games, we can refer to games such as TeamUp [2], Escape From Wilson Island [31], and HeatMeUp[22].

TeamUp is a collaborative serious game with the main goal of fostering teamwork [2]. Four players play this game; each

player takes the role of one avatar. The game consists of several challenges that require close collaboration of the teammates. Each challenge is designed for a particular aspect of effective teamwork, including leadership and communication. The players of the game are physically present in the same location. They are allowed to communicate verbally but are positioned in such a way that they cannot look at each other's screens.

Escape From Wilson Island is another example of a serious game with a focus on collaborative gameplay that fosters the development of social skills such as team-work, communication, and coordination [31]. This game is an online role-playing game in which four players find themselves on an island where the goal is to escape from it by reaching a neighboring island and igniting a rescue sign through close collaboration.

HeatMeUp is a collaborative serious game with the goal of collaborative path finding. It is a two-player game with the roles of a fire fighter and a fire chief. The fire fighter interacts with the game using a gamepad and the fire chief is placed in the control room and is in charge of three screens. The collaboration of the players in this game does not take place through verbal communication but rather through game objects [22].

Collaborative games with Sifteo Cubes

Two collaborative games designed for the Sifteo Cubes will be discussed: Fat and Furious [25] and Tangicons [27].

Fat and Furious is a multiplayer collaborative game of the type runner. The main character of the game is a hamster that takes a path of the crossroad randomly, and its speed increases over time. The player loses the game when the hamster takes a path and there are no other cubes connected to that side of the current cube, or when it reaches an obstacle in a cube. Every time the hamster leaves a cube an element may appear on the cube, and the player then needs to use alchemy to get rid of this obstacle. Furthermore, certain hand motions (tilting, shaking, and repeatedly touching) can be performed in order to remove or transform the obstacles [25].

Tangicons is described as an educational non-competitive collaborative, targeting children between the ages of six and nine. Tangicons foster algorithmic construction and reasoning as well as discussions among the players [27]. This collaborative game is played in teams of four players with a total of six Sifteo Cubes and a laptop. Each player has a cube as a personal token that represents an action to be executed. Each player's cube represents an action, and the players have to discuss the order in which these actions are to be executed.

Collaborative games with Oculus Rift

The Oculus Rift can be used for traditional co-op or multiplayer games like Team Fortress 2 or Left 4 Dead 2 to provide a more immersive experience. But the Oculus Rift also isolates the player. This isolation has been used to create asymmetrical co-op experiences, where one player uses the Oculus Rift while the other player(s) use another way of interaction. Two games use the Oculus Rift this way.

⁴<http://www.ea.com/fifa>

⁵<http://www.simxp.com/en/simulations-games/teamup/>

⁶<http://goo.gl/pBZxFG>

⁷<http://www.valvesoftware.com/games/portal.html>

Black Hat Oculus⁸ is a two-player heist co-op game. The player with the Oculus Rift is a bandit that navigates through a building while avoiding guards and looking for loot. The second player is a hacker that has access to a top-down view of the building. He has a greater field of view than the bandit, and can communicate with the bandit by using the keyboard. The player with the Oculus can read these messages at the center of the screen. The hacker needs to communicate the location of loot, enemies, and tactics to the bandit. The game is over when an enemy sees the bandit in the building.

In Keep Talking and Nobody Explodes⁹ the goal is to defuse a bomb before it explodes. One player plays the role of the person in front of the bomb using the Oculus, while the rest of the players are the experts on bombs defusing. The player in front of the bomb can see and interact with the bomb using the Razer Hydra game controller¹⁰, while the others have a set of instructions to defuse bombs. The player with the Oculus needs to describe the bomb to the experts, so that they can give proper instructions to diffuse it before the time runs out.

Impact of interaction modes on game experience

Previous work that investigated the effect of interaction modes or controller types on game experience is limited. If different input devices are compared, the focus is usually on differences in performance with respect to the selecting or tracking of objects, e.g., [21], [14], and [12]. In these works, devices such as the Nintendo Wii Remote, Xbox gamepad, a track mouse, and standard input (mouse and keyboard) are compared. With respect to comparisons of input devices regarding game experience, we can report the following work. Nacke [20] compared the Playstation 2 game controller with the Wii remote and Nunchuk on subjective experience and brain activity measured with electroencephalography (EEG). Limperos et al. [15] reported greater feelings of control and enjoyment with the Playstation 2 than with the more technologically advanced control of Nintendo Wii. Gerling et al. [10] examined the impact of mouse and keyboard versus gamepad control in first-person shooters using the PC and PlayStation 3. No significant impact on overall player enjoyment was found. McEwan et al. [17] compared a standard Xbox 360 controller (as an example of a directionally mapped device), the Wireless Speed Wheel for Xbox 360 (as an example of a device using incomplete tangible natural mapping), and the Xbox 360 Wireless Racing Wheel (as an example of a device using realistic tangible natural mapping) in a racing game. Generally, participants performed better with the controller, followed by the Speed Wheel and then the Racing Wheel. However, the more naturally mapped a device was, the higher results were on perceived levels of game involvement. The participant's positive response to the play experience seems to be related to the degree of natural mapping of the control device and not to their performance or capability with that device. Skalski et al. [29] showed that spatial presence and enjoyment were both affected by the perceived naturalness of the controllers. In their study, they used

⁸<http://globalgamejam.org/2014/games/black-hat-oculus>

⁹<http://goo.gl/9aNilkv>

¹⁰<http://sixsense.com/hardware/razerhydra>

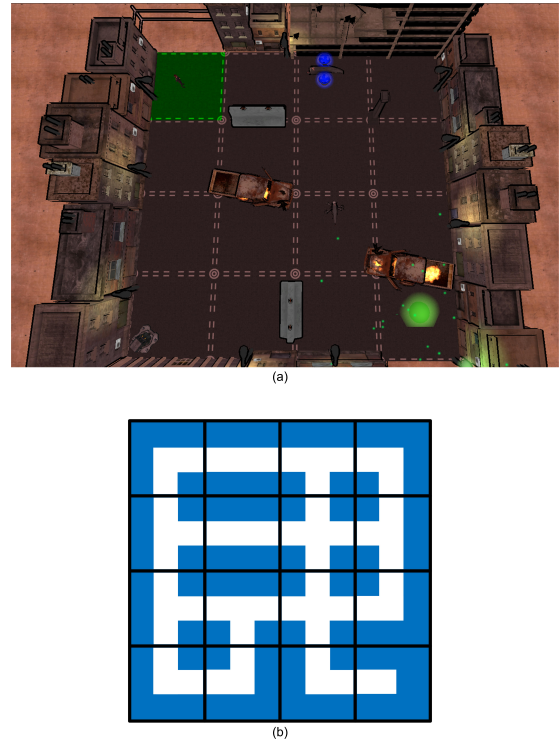


Figure 1. Maze as seen with the Oculus Rift (a) and the Sifteo Cubes (b)

a Nintendo Wiimote, a gamepad, a steering wheel, a keyboard, and a joystick. Pietschmann et al. [24] also conducted a study comparing the Nintendo Wii Remote and a classic gamepad controller with respect to immersion and presence. Birk and Mandryk [3] studied the effect of three controllers (Microsoft Kinect, Playstation Move, and Xbox GamePad) on the player's perception of themselves during play (in-game player personality) in a targeting game and found that the choice of the controller could affect the in-game personality. No work including the Oculus Rift or the Sifteo Cubes for comparison could be found.

MAZE COMMANDER

Maze Commander is a two-player collaborative tile-based maze game. The objective of the game is to escape from a maze while avoiding enemies and hazards (explosions and traps). The enemies are always patrolling over specific paths (they do not chase the character), moreover certain tiles explode after a certain time interval. Traps are tiles that kill the character upon contact. These traps are not visible until the character steps over it. The game is over when either the player ends up on the same tile as an enemy or a trap, or when the player is on a tile when it explodes.

As mentioned previously, the two players use different interaction modalities to play the game: one uses the Oculus Rift and the other uses the Sifteo Cubes. The game experience is different for each player since the view of the game as well as the possible actions are different for each interaction mode. The player using the Oculus Rift cannot move the character in the game, but has a 3D top down view of the whole maze and can see the enemies, the character, and the explosions.



Figure 2. A Sifteo Cube showing the tile where the character is



Figure 3. The 5 different patterns that the cubes can have

The maze is visualized to this player as a grid of tiles (see Figure 1 (a)). The Sifteo Cubes also visualize the maze but in a different way (see Figure 1 (b)). A Sifteo Cube can also visualize a tile, but mainly shows possible paths for moving (coloured white). However, the player with the Sifteo Cubes does not get the view shown in Figure 1 (b). He only has four cubes: one showing the tile containing the character (i.e., the character cube, see Figure 2), the three other cubes can be used to move the character to the right direction.

The objective of the player with the cubes is to move the character through the maze by manipulating the cubes (see below for the rules) based on the instructions given by the player with the Oculus Rift. The objective of the player using the Oculus Rift is to provide detailed instructions to his/her team mate on what pattern to select on the Sifteo Cubes, which direction to move to and when to do so in order to reach the exit of the maze (indicated with a green light).

At the start of the game, the character cube shows the tile where the character is at the beginning of the game and the other three cubes show random patterns. There are five possible tile patterns (see Figure 3). In order to move the character to a new tile, the player needs to join the character cube with another cube showing the desired direction for the move. As part of the rules of the game, only one cube can be attached in either direction of the character cube (the motivation for providing three cubes for this is given in the design section). In order to change the pattern of one of the random tiles (if the desired pattern is not available), the player can pick up a cube and shake it. The shaking motion will switch between the different patterns. The cube can also be rotated in order to have the desired orientation.

When the player connects a cube to the character cube, and the pattern and orientation of the cube does not match the one of the maze for that position, then the cube color will switch to red (see Figure 4 (a)) to show the player that this is an invalid combination. If the combination is valid, the cube colour will switch to green (see Figure 4 (b)). Once a correct combination is recognized, the player can observe the ongoing activities on the connected tile (e.g., the existence of an enemy, see Figure 4 (c)). The character will not move to the desired destination tile unless the player clicks on the destination tile (see Figure 4 (b)). Once this action is finished, the destination tile becomes the new character tile and the same procedure follows.

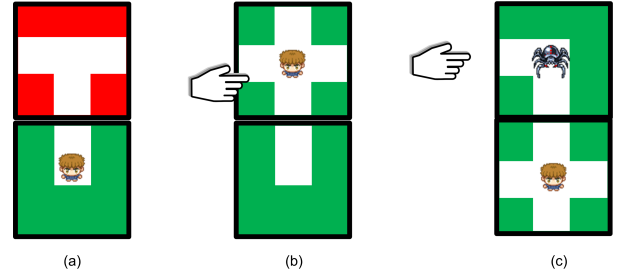


Figure 4. Character movement

Maze Commander has three levels with increasing difficulty. The difficulty is in terms of the size of the grid, the number of enemies, the amount of safe tiles, and the distance between them. A safe tile is a tile without hazards, so the player can stay on that tile as long as he wants and define a strategy.

The first level has 13 tiles, five of them are safe, and the shortest path between two safe tiles has a maximum distance of three. There are two enemies and one explosion hazard on this level. The first two tiles of the maze are safe to allow the player to get familiar with the tiles and moving. The second level has 16 tiles arranged in a 4x4 grid, five of them are safe, and the shortest path between two safe tiles has a maximum distance of four. There are two enemies and one explosion on this level. The player does not start on a safe tile and needs to move at least two tiles to reach a safe tile as soon as the game commences. The third level has 25 tiles arranged in a 5x5 grid, three of them are safe, and the shortest path between two safe tiles has a maximum distance of eight. There are four enemies, one explosion, and a trap. The player starts on a safe tile, and from that tile on there are only two additional safe tiles: the exit, and the center tile. The minimum distance from those two tiles to the exit is eight, so the players have to communicate and act fast in order to win the level.

DESIGN

Maze Commander was designed based on the collaborative game design guidelines proposed in [31]. Four of the proposed guidelines were considered relevant and were taken into account during the design process of this game. We list them below. For each guideline, a brief explanation of the guideline is given and how it is related to Maze Commander.

- **Common goal/success:** The game must be designed in such a way that both players have the same goal, and succeeding in the game means success for both. In Maze Commander both players have the same goal, i.e., escaping from the maze. Since accomplishing this requires rather close collaboration between the players, the success and failure in terms of achieving the objective is common.
- **Heterogeneous resources:** The game must be constructed in such a way that each player has a unique tool or ability that would enable that player to perform unique tasks. In Maze Commander, this guideline is clearly followed. The player who interacts with the game using the Oculus Rift is in possession of a unique resource, being an overview of the whole maze, enabling him/her to strategize and provide instructions to the other player. The player who interacts

with the game using the Sifteo Cubes, is in possession of a different unique resource, being the ability of moving the character and viewing patterns that can be used.

- **Collaborative tasks:** The game must contain tasks that are only solvable when the players collaborate. Maze Commander follows this guideline. It is virtually impossible for either player to finish a challenge without the help of the other. Although the player interacting with the Sifteo Cubes actually moves the character around, without a strategy and guidance from the player with the Oculus Rift, accomplishing the task would not be possible. These two roles are equally vital for accomplishing the task.
- **Communication:** Communication is a vital component in collaborative learning. In Maze Commander players have the possibility to communicate with each other in different ways, the most common one is verbal communication. On the other hand other modes of communication have also been observed in our evaluation, for example using hand gestures to describe the pattern of a tile that is required. This game is designed in such a way that bi-directional communication between the players is needed. The player with the Sifteo Cubes also needs to communicate certain information to the other player, for example describing the shape of the patterns he or she sees on the cubes in order to help the other player recognizing the tiles in the maze.

The decision to use only four cubes was made in order to make a balance between the levels of challenge the players would experience and their skills. If more than four cubes were given to the players, planning all the moves ahead would have become easier after a few tryouts of the game; this way the player has only a limited number of possibilities for pre-arranging the movements they want to make and therefore they have to act fast on finding the correct pattern and orientation while they are on the move. On the other hand, if less than four cubes were used, the game would have become extremely challenging, since the players had to switch between tile patterns and orientations extremely fast. Based on the difficulty levels we designed for this game, four Sifteo Cubes seemed to be the best trade-off after some trial sessions.

As mentioned in the previous section, a tile in each level explodes after a specific time interval, but the information about the frequency of the explosions is not given to the players, this choice was made deliberately, firstly to challenge the player with the Oculus Rift to find the timing in order to give the “go ahead” signal to the other player, as well as challenging the player with the Sifteo Cubes to act quickly on moving the character before a new explosion occurs; secondly to encourage the players to communicate effectively, efficiently, and in a timely manner.

Furthermore, as mentioned in the previous section, the game starts on a safe tile in levels one and on an unsafe tile in level two. This decision was taken to challenge the players to act faster in the second level in order to avoid losing the game. This decision was made based on the assumption that after finishing the first level, the players have already established an effective communication protocol and are able to communicate more effectively and efficiently.

Maze Commanders was designed with the aim of developing certain skills. For players interacting with the game using the Oculus Rift, these skills are visual perception [16], pattern recognition, strategising, and problem solving [7]. For those interacting with the Sifteo Cubes, skills such as spatial reasoning [16] and decision making [7] are targeted. These skills target the individual player, but team skills such as collaboration are also considered.

IMPLEMENTATION

Maze Commander consists of two applications running simultaneously: the Oculus Rift application and the Sifteo Cubes application. The Oculus Rift application is written in C# in Unity3d, while the Sifteo Cubes application is written in C# using the Sifteo SDK. In order to synchronize both applications, sockets using TCP/IP are used. Each application connects to two ports, one for sending information and one for receiving information. The communication between the two applications is in the form of a full duplex, meaning that both applications act as client and server.

The Oculus Rift application needs to notify the Sifteo application when a new level is loaded or when the game is over. It also constantly streams the position of the enemies. The Sifteo Cubes application receives the commands and executes the corresponding actions. If the enemies are on the tiles currently visible on the cubes that are rendered, the Sifteo application also streams the position of the character.

The graphics on the Sifteo Cubes have five different sprites, one for the character and four for the different enemies, the paths are generated using Sifteo SDK primitives. We did not include animations in this version to avoid lags on the cubes.

Although our tests were made using one computer, acting as both server and client, the network architecture chosen allows us to run the two applications on different computers, and we plan to do that in the future since we found it is too demanding for a single computer to run both programs at the same time, causing lags under certain circumstances.

EVALUATION

Although the Maze Commander was developed to investigate the effect of interaction modes on the learning experience, we first evaluate the overall game experience and the collaborative facet of the game. In addition, we explored the differences in game experience between the two modes of interaction. Based on our evaluation, we provide initial design recommendations for collaborative games combining Oculus Rift and Sifteo Cubes.

Methodology

In order to evaluate the game experience and the collaborative aspect of Maze Commander, we have chosen a formative evaluation design composed of three components. The first component evaluates the user’s game experience and collaboration through a within-subject factorial research design. Secondly, we have further explored the collaboration and communication aspect by observation. In addition, a semi-structured interview and additional observation metrics were used. This gave us the possibility to determine how and why

users experienced certain game experience factors and collaborative issues.

Data Collection

In the first component of the evaluation design, the game experience and social presence questionnaires developed by Kort et al. [6] were used. The questionnaires contain in average four to six questions on a 5-point Likert scale to measure the game experience in terms of competence, flow, immersion, tension, challenge, negative, and positive affect. Competence includes, among others, skillfulness and successful rate. A factor to determine flow is given by how much they forgot the world around them, where immersion includes for example how imaginative a user felt. Tension was partly constructed by the degree of annoyance, and negative affect by how much a player thought about other things. Finally, the level of effort contributed to the challenge factor and the degree of fun was included in the positive affect factor. The social presence is factorized by empathy, negative feelings, and behavioral involvement. Empathy is represented for example by being connected to the other player. The negative feeling factor included revengefulness, and behavioral involvement was measured, among others, by how close the player paid attention to the other player.

Besides the social presence measured by the questionnaire mentioned above, the evaluation of the collaborative aspect of Maze Commander is also achieved by the observation of collaborative metrics. We have used the collaborative metrics for cooperative games specified by El-Nasr et al. [28], which include excitement together, worked out strategies, helping, global strategies, waited for each other, and got in each others' way. In addition, we have paid significant attention to how players communicated during play sessions. This extra metric could give us more insight in the explanation of, for example, tension or negative affect since communication is essential in Maze Commander.

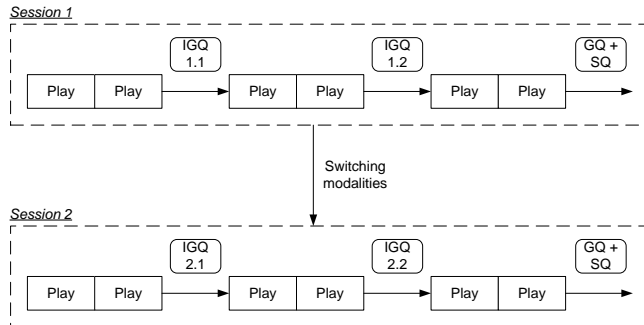


Figure 5. The evaluation study's setup. IGQ: Short in-game questionnaire, GQ: Core game experience questionnaire, SQ: Social presence questionnaire.

Procedure

Since we are interested in the overall game experience as well as the in-game experience with both modes of interaction in Maze Commander, the evaluation design includes two evaluation sessions with multiple rounds (see Figure 5). A round consists of two attempts to complete the level. In the first session one player plays with the Oculus Rift while the

other plays with the Sifteo Cubes. Before starting the evaluation sessions the players could try the game. After the try-out, participants played three rounds where each round was followed by an in-game questionnaire (IGQ) except for the third round. This in-game questionnaire is a shortened version of the post-game questionnaire (GQ). After the third round, the post-game (GQ) and social presence (SQ) questionnaires were completed. Note that the in-game, post-game and social presence questionnaires were developed by Kort et al. [6]. Since we opted for a within-subject design, both players switched modalities and played again three rounds with the same procedure as in the first evaluation session.

Participants

We had sixteen participants aged between 19 and 36 years, with an average of 23.62 years. Twelve participants were male and four female. Furthermore, three users did not have any game experience while seven mentioned that they were intermediate frequent players and six participants had an advanced level of game experience. Finally, two out of the sixteen participants were colorblind.

Results

In the analysis of the results, we have used the mean of the relevant questions to construct the seven game experience and the three social presence factors. In addition, a t-test is applied to determine differences between the modes of interaction in each session. Cross-session statistical comparisons were not appropriate due to the learning effect and the increase of difficulty in the game's levels.

Overall Game Experience

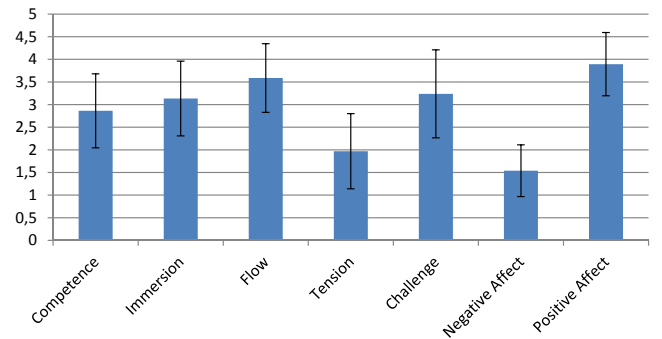


Figure 6. Overall Game Experience (GEX). The error bars indicate the standard deviation.

The overall game experience results indicate a promising positive evaluation of the Maze Commander game. Figure 6 shows the means with the standard deviation for all seven game experience factors. The overall game experience means are given by combining the factor's mean of the first and second evaluation session. Note that the lowest possible value is 1 since the results are based on a 5-point Likert scale. We can observe a positive evaluation for flow and challenge where competence is neutral. According to Csikszentmihalyi [5], a good game design should include closely related values of competence and challenge in order to keep the player in the flow of a game. As illustrated in Figure 6, we have achieved a positive flow by the flow value itself and by the

minimal difference between competence and challenge. Furthermore, a positive evaluation is given for immersion and positive affect. It is worth to mention that, although the game is not using a first person view for the Oculus Rift, the immersion is still positive even though the Oculus Rift is often promoted to be used in first person view. The good score on positive affect was also observed during the play sessions. Participants had fun, they laughed, made jokes, and expressed their excitement verbally. Although some players looked quite serious and were utterly immersed in the game, upon completing a level they expressed their happiness and joy explicitly. Moreover, the results show a low but not “null” value for tension and negative affect (i.e 1.96 respectively 1.53 with lowest possible value 1). In the observation of several play sessions, we have seen that some pairs of players had some difficulty in verbally communicating with each other. Participants using the Oculus Rift described the scene in depth but did not provide the accurate information which was needed to form the path with the Sifteo Cubes. This sometimes lead to discussions between the two participants where the player with cubes became irritated. A second reason could be that two participants were taking a dominant role over the co-player. When the co-players did not tell them how they needed to arrange the cubes, or, in the other session, they did not place the cubes in the proper way, we could observe some frustration.

Social and Collaborative Aspects of Maze Commander

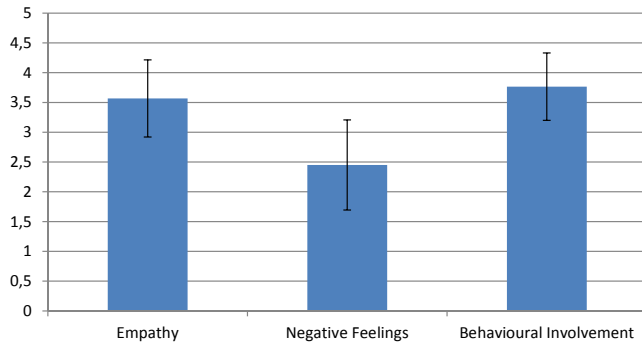


Figure 7. General social presence. The error bars indicate the standard deviation.

Since Maze Commander is a collaborative game, we have measured the social presence in terms of empathy, negative feelings, and behavioral involvement. The results are given in Figure 7. Empathy as well as behavioral involvement have a positive score. Due to the game design, the behavioral involvement’s score could be expected since it measures factors as the degree of actions where players are dependent on each other. In Maze Commander one player needs to wait for instructions of the other player before he can continue in the game. On the other hand, the positive score for the empathy factor illustrates that players found it, among others, enjoyable to play with each other.

Besides the social presence quantitative results, we also have used the previously mentioned collaborative observation metrics. We could clearly observe the excitement-together metric

where participants verbally expressed joy, and bodily expressions were noticed between play sessions and when accomplishing the challenges of the game. We could also observe that strategizing was a major activity in the game play. Only one pair played the game with an ad-hoc try and error strategy.

All other participants consulted each other in some degree. This leads us to the metric worked out strategies, which was definitely observed. Players consulted each other to determine a step by step strategy in order to reach the end goal. Furthermore, when a player waited for the other player to give comments or to do an action, the waiting player did not get frustrated or annoyed. Moreover, when players had to wait for the other player, they focused on their own responsibilities. For example, a player with the cubes waiting for instructions from the Oculus player, constructed the correct path with the cubes in the meantime. This is due to the fact that they had the knowledge about the patterns of the path from previous play sessions. A remarkable observation is the fact that they did not helped each other in the first evaluation session. In contrast, some participants helped the other player after switching modes of interaction in the second session. However, the majority of participants did not use their prior knowledge of the other modality to help the other player or to communicate in better terms. For example, a player which had played in the first session with the cubes started to describe tiles in terms of go straight, go left or right but they did not describe the pattern of the tile. Although they had played with the cubes and knew that they had to determine the path before the character can move, they did not use this knowledge in the second session.

Differences Between Interaction Modes

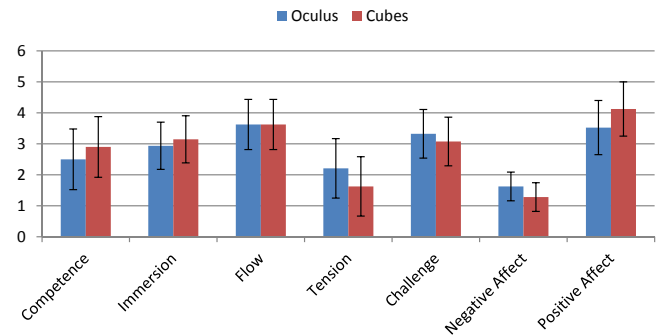


Figure 8. Game experience of the first session. Standard deviation is given by the error bars.

In addition to the game experience and collaborative evaluation, we have explored game experience differences between the two modes of interaction. The game experience results for each mode of interaction in both evaluation sessions are given in Figure 8 and Figure 9. We did not found any significant difference between the game experience of the Sifteo Cubes and the Oculus Rift within the two evaluation sessions. The results of the conducted t-test for both evaluation sessions are given in Table 1. This means that players experienced an equal level of game satisfaction. Note that we cannot provide

GE Factor	Interaction Mode	First Session				Second Session			
		Mean	SD (σ)	t -value	p -value	Mean	SD (σ)	t -value	p -value
Competence	Oculus Rift	2.500	0.979	−0.966	0.350	3.225	1.092	0.842	0.414
	Sifteo Cubes	2.900	0.641			2.825	0.781		
Immersion	Oculus Rift	2.937	0.760	−0.491	0.631	3.541	0.911	1.448	0.170
	Sifteo Cubes	3.145	0.927			2.916	0.811		
Flow	Oculus Rift	3.625	0.810	0.000	1.000	3.800	0.785	1.213	0.245
	Sifteo Cubes	3.625	0.795			3.300	0.861		
Tension	Oculus Rift	2.208	0.958	1.360	0.195	1.666	0.816	−1.747	0.103
	Sifteo Cubes	1.625	0.744			2.375	0.805		
Challenge	Oculus Rift	3.325	0.785	0.457	0.655	3.325	1.185	0.200	0.844
	Sifteo Cubes	3.075	1.334			3.225	0.766		
Negative Affect	Oculus Rift	1.625	0.462	1.389	0.187	1.437	0.691	−1.152	0.269
	Sifteo Cubes	1.281	0.525			1.812	0.608		
Positive Affect	Oculus Rift	3.525	0.874	−1.693	0.112	4.250	0.542	1.673	0.117
	Sifteo Cubes	4.125	0.489			3.675	0.806		

Table 1. Results of the two evaluation sessions' t -test between the two interaction modes for each game experience factor

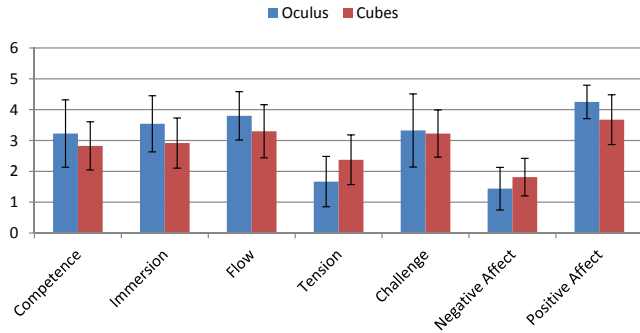


Figure 9. Game experience of the second session after switching the modalities (i.e. Oculus Rift and Sifteo Cubes). The error bars give the standard deviation.

a statement concerning differences between the two evaluation sessions due to the significant differences in baseline such as the increase of difficulty and learning effect.

Finally, the participants found the combination of the two modes of interaction very promising and innovative. Six participants preferred both modes of interaction and both modes were seen as a very fun alternative to keyboard and mouse. The Oculus Rift was preferred by six participants, mostly because of the imaginative immersion and the presence of a visual overview of the game scene. In contrast, four participants were in favour of the Sifteo Cubes since they felt they had explicit control over the game by moving the character from one tile to the other.

Lessons Learned

Based on the evaluation, we can formulate some observations that might be taken into account when designing collaborative games with the Oculus Rift and the Sifteo Cubes.

Explicit control for the Oculus Rift

As illustrated earlier, some users preferred the Sifteo Cubes due to a lack on perceived explicit control when playing with

the Oculus Rift. Although the person with the Oculus Rift implicitly has more control since they need to explain the next move and are responsible to determine the optimal path to the end goal, certain players did not experience being in control of the game when they were playing with the Oculus Rift. For these cases, one could adapt Maze Commander with the possibility to move the character in the Oculus Rift interaction mode. Nevertheless, the collaborative aspect and separation of responsibilities should be kept.

Allowing to communicate through different channels

Although we had expected to observe only verbal communication, almost all participants using the Oculus Rift also used gestures for communication. Gestures included drawing for example a cross in the air or small drawings on the table surface with a finger. Additionally, left and right directions were often not used but replaced by commands such as “to the wall” or “to the door”. One participant, playing with the Oculus Rift, even mentioned “I need a T-tile directed to your belly” while pointing to his teammate’s stomach.

The importance of strategizing moments

Most participants collaboratively strategized to some degree. We observed four categories of strategizing behavior. Only one group played the game without any strategy but with a try and error approach. All other pairs of participants strategized on three different moments. Some participants only consulted each other about strategies during the breaks between play sessions, while other participants used ‘safe’ tiles to discuss the next steps. Nevertheless, two pairs of players took their time on both ‘safe’ tiles and during the breaks. One group even took five times more time than the other players in each game session to determine a strategy.

Skills and personality adaptations

During the evaluation sessions it became clear that players significantly differ in their interaction with the two provided modes. Some players were very skillful with the Sifteo Cubes, while others could give very clear instructions when

playing with the Oculus Rift. This indicates that the direction for our future work to relate the mode of interaction for an individual to their learning style or strong intelligences may be useful to explore.

Interacting with the Sifteo Cubes

When interacting with the Sifteo Cubes, some users experienced difficulties in finding the proper pattern. It was clear to them that they could join the cubes to form the path, but changing a cube's pattern by shaking the cube was not always perceived as a natural interaction. They had to shake the cube several times until the correct pattern was shown on the cube. Often the shaking was too fast or too slow which lead to skipping the correct pattern and eventually losing the game. Therefore, common or critical actions could be done by more common interactions such as placing the cubes together or clicking on the cube's screen. On the other hand, problems with the shaking-interaction could be solved by providing some learning time. Whether the problem with the shaking is a fundamental problem or only due to the inexperience of the player with the device should be investigated further.

DISCUSSION & FUTURE WORK

Based on the evaluation results, we can conclude that the players had an overall good game experience, which we associate with the game design as well as with the novel modes of interaction used. Furthermore, no significant difference in the overall game experience between the Oculus Rift and the Sifteo Cubes was observed, which suggests that both interaction modalities were perceived equally positive. However, personal characteristics, such as learning style, were not yet taken into consideration for selecting the participants. In comparison with other collaborative serious games with good gaming experience, our game managed to provide a good gaming experience for its players, although a different interaction modality for each player was deployed. This is of importance, since the combination of different interaction modalities have the potential of delivering a higher level of game experience.

In future work, we will evaluate both game experience and learning outcome (i.e., increase of communication and collaboration skills) of players in a setting in which each player would use an interaction modality that is in accordance with their learning style and/or strong intelligences. One way to measure the effectiveness of such experiment could be based on measuring the performance of players. In the context of this game, one measuring factor of performance is the quality of communication. Therefore, a closer study on the communication aspect of the game should also be performed.

CONCLUSIONS

In this paper, we have introduced a collaborative game called Maze Commander that uses two novel interaction modalities. The design of this game was explained and motivated. With an experiment, we have evaluated the game experience of 16 participants and observed that the game provided a good gaming experience in general. Furthermore, based on our evaluation,

we have gained insight on design decisions important for collaborative games with the two given interaction modes.

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