Shared Augmented Reality: Developing a Multiplayer AR Mobile Game to Study Playability

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 Preface

This is a documentation of the research and study I performed at the company Tar Valley during the last 10 weeks of my education. I have worked with Tar Valley previously regarding an AR smartphone game supporting multiplayer. In this project, I implemented a prototype game building on our previous ideas and executed tests to study its Player Experience. Developing and testing an application in the time-span of this work has been difficult. But it enabled me to grow and gain experience in a field that has always interested me since I was young. I want to thank everyone at Tar Valley for their support and interest in the project. I would also like to thank Patrik Holmlund and Johannes Hirche for providing help and guidance during the course of my education. My hope is that this paper will give insight into developing multiplayer AR games and somewhat extend on the previous works of Kalle Jegers in his evaluation of the Pervasive GameFlow Model.
ABSTRACT

The purpose of this study has been to investigate if the Pervasive GameFlow Model is suitable for evaluating Player Experience in Augmented Reality games. The work has described a definition of Augmented Reality, how it generally operates and reviewed common challenges when developing Augmented Reality applications. A prototype game has been developed, based on a previous concept of merging board games with computer games using Augmented Reality. After development, the game has been tested with a method based on the Pervasive GameFlow Model. Results showed the model to be suitable for future tests and evaluations, but did not produce data for evolving the game design. Generating such data would require execution of additional testing methods.

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1. **INTRODUCTION**

1.1. **ABBREVIATIONS AND TERMS**

- Human-Computer Interaction - HCI, research field that studies human-computer interaction
- Pervasive GameFlow Model - PGM, model for evaluating playability of pervasive games
- Heuristic, defines a practical method for problem-solving
- User Interface - UI, connection between user interaction and a system's functionality
- User Experience - UX, users' opinions in regards to a used product, system or service
- Player Experience - PX, players' opinions in regards to a played game
- Usability, how efficient a software user achieves desired results
- Playability, how efficient a game provides desired entertainment to player
- Software Development Kit - SDK, set of development tools to help in creation of software
- Application Programming Interface - API, interface that simplifies programming by abstracting functionality of code collection
- Augmented Reality - AR, system that enhances the perception of the real world with virtual data.
- Virtual Reality - VR, simulated environment completely experienced in virtual data
- Unity, cross-platform game engine
- Vuforia, SDK for developing AR applications
- PhysX, SDK for multi-platform physics simulation
- Direct3D, API for rendering graphics on Windows platforms
- OpenGL, API for rendering graphics independent of platform
1.2. **Prelude**

Games are an entertainment phenomenon in today’s society, providing exiting and fun experiences for their users. In regards to video games, the concept of these experiences can be called Player Experience. The term PX has evolved from the term User Experience. Both are part of the research area of Human-Computer Interaction which study the design of interfaces between humans and computer technology. The concept of UX is often used in studies to determine a system’s usability for example as described by Nielsen [17]. It is based on determining usability attributes that can be used to systematically measure and approach a good experience in using a system. Since games are meant to entertain its players, the usability of games becomes its ability to be ‘played’. As introduced by Desurvire et al. [5] with the Playability model for studying PX for computer games. Though a proven model for testing UX for traditional computer games, it has not been adapted for the relatively new concept of Augmented Reality games.

For the purpose of this paper a simple definition of AR was needed. As described by Azuma et al. [3][2], AR is a system that blends virtual information with an interactive real-time environment. It is often used to enhance a user’s sight by aligning 3D computer-generated objects with real geometry. But it could theoretically augment any sense of the user such as with sounds or even smells. AR as a system began in the late 1960s as a head-worn display which enabled the wearer to see virtual information mixed with physical objects [25]. The concept did not receive its modern name until the early 1990s as part of a proposed solution to assist aircraft construction workers [4]. It would be another decade until AR was used in gaming by 1998 [26] with a system that let multiple users play Mah-Jongg together using virtual game pieces and boards. The following 5 years would bring more AR games [24][20] which focused mostly on adapting engaging game mechanics to AR. As discussed by Wagner et al. [28] these games still weren’t practical enough for the average consumer. In their research they focused on studying the usability of AR as a system and how to make it more approachable by users. Though the usability aspect of AR has received many contributions in the recent years ([7][14][15][23] to name a few), there is still a lack of standard practices in PX for AR games.
To find a suitable structure for evaluating playability in AR games, the genre of pervasive games has been investigated. It is a varied category explained further in the Theory section, which AR games can often be categorized into. A thesis by Jegers [10] attempted to create a model of playability for pervasive games called the Pervasive GameFlow Model. This project have used some of the findings and methods from his work to conduct tests. For the purpose of evaluating its applicability to a game concept further explained in the next section.

1.3. BACKGROUND

About three years ago Tar Valley had an idea of a game that combined virtual gameplay with the real world. The project was called We AR Fighters and is based on merging analog games such as cards or board-games with virtual gaming. The idea has been explored to find ways the game could be played using AR. The purpose was to utilize the technologies as a core for the PX. Multiple prototypes concluded three core findings for the design:

- Game-play must feel natural and be practical to use with AR.
- Mechanics should require less direct input from the player, focusing more on observing.
- Game-play should be limited to shorter consecutive sessions to not tire the player.

This was the result of designers and developers personally play-testing the different game-play implementations. The design decisions thereby was mostly based on their opinions and not confirmed on a broader spectrum. It was decided to research into how the concept could be tested more empirically. Since there are a limited amount of standard practices for evaluating PX for AR games.

1.4. GOAL AND PURPOSE

The goal of this work is to implement a prototype game that can produce an AR experience inheriting the core findings of We AR Fighters. To test the prototype with the PGM and analyse the results. For the purpose of generating game-play feedback and determining if the model is applicable to the concept of the prototype and future similar games.
1.5. Limitations

The goal of the work was changed after the first 2 weeks of the project. The mission initially only had two main objectives. Gather information about the currently existing testing methods and AR techniques, and develop a small demo game that implemented the findings. The game was also meant to be used with the testing methods in the future. The change did not affect the work already completed because it mostly consisted of research that was needed regardless. It did disturb the planning for the project which could have affected the efficiency of work routines in some aspects.

1.6. Unity

Unity [27] is a cross-platform game engine suitable for both 3D and 2D development. It offers a scripting API in C# supporting several plugins and tools. The API utilizes an entity component system that developers can extend on to create game mechanics quickly. The engine provides an interface for physics simulation using PhysX[18] and rendering with a number of different graphics APIs such as Direct3D[16], OpenGL[11] and more. The engine have been used to setup a foundation were the major game mechanics could be implemented. The mechanics was expanded upon the provided component system and adapted to the engines built-in network structure.

1.7. Vuforia

Vuforia [21] is one of the most widely deployed SDKs for AR today and is free to use for development purposes. It provides an easy way to setup different AR environments in the Unity engine. The SDK offers a simple interface for different AR techniques such as marker tracking and markerless tracking. Vuforia’s target manager have been used to setup the tracking system that anchors virtual elements to the real world. This made all of the game mechanics easy to adapt to the AR environment. The technique uses markers to align the game world with the cameras viewpoint and will talked about more in section 2.
1.8. **Social, Ethical and Environmental Considerations**

One aspect of pervasive games that are different from traditional games is the element of ‘when’ and ‘where’. They can be available to play in almost any place and time. This is also true for the concept of the game tested in this work to some extents. It can be seen as an intrusion on the everyday life of players since its invitation for play are possibly limitless. This could be heavily misused when creating a product for a younger audience when also containing microtransactions. Which some studies already has discussed in regards to vulnerable users overspending on these systems [12]. On the other side, the game mechanics implemented in this work can have a positive effect on players social life. Since it is played much like traditional board games, and players are encouraged to meet and socialize with each other in the real world.
2. Theory

2.1. Augmented Reality

2.1.1. Marker-based Tracking

AR creates the illusion of virtual content existing in the real world. This is achieved by presenting the virtual content mixed with some sort of representation of the real world, such as a camera's view on a display screen. To convince the observer that the content exist in the real environment, it must be presented correctly in regards to what exists in that environment. Calculating the necessary adjustments to correctly display the virtual data is done through a process called tracking. Marker-based tracking \cite{22} uses the video input of a camera to detect and track specific target images. The targets are used to anchor virtual information in the real scene (as seen in Figure 1). It does this by finding the camera's position and orientation in regards to the targets real environment placement.

Figure 1: Environment augmented with a virtual object using a marker
2.1.2. Markerless Tracking

The term markerless tracking can be used for an AR system that does not require any prior knowledge about the environment to be augmented. Simultaneous Localisation and Mapping also known as SLAM, is a group of techniques that enables such tracking. It does this by building a map of the environment while simultaneously tracking the cameras position. There is a negative aspect of SLAM when it comes to AR for phones. That most available SDKs which offers the functionality, can only be deployed on a limited number of devices [8][1].

![Figure 2: Placement of virtual object in environment without assisting markers](image)

2.1.3. Challenges

Maintaining a mixed reality environment can be very difficult. If the virtual objects are not aligned properly, the illusion of a merged game world will suffer. A common term for this is called the registration problem [3][13]. It occurs when the system is unable to track the world which causes incorrect placements or a complete loss of
orientation. Solving the problem is very difficult because it is rooted in many elements surrounding the system. Some that are impossible to control by the developers such as bad lighting conditions or obstructed view for the devices camera.

External components such as the markers needed with marker-based tracking can become a user convenience problem. Expecting the player to bring and positioning a marker before playing is a luxury of testing. While in realistic cases it could potentially alienate groups of players. It is also a matter of social acceptance at which lengths some players will be willing to go for experiencing the game. Therefore it is vital to ensure the external setup to be as natural and comfortable as possible.

Applications that utilize AR should also consider the physical environment of the user. Since distracting players when they also need to be aware of their surroundings can result in an obstruction of their physical safety. Games that are too engaging or require too much concentration can put both the player and other bystanders in danger as mentioned by Kipper [13]. It is an important element to factor when designing a game and in what ways it will be encouraged to play.

2.2. Usability Testing

2.2.1. Models and Frameworks

Generating information regarding usability is a well studied field in HCI. The most traditional process consists of creating a model or framework that describes a phenomenon of user experience. For example the Playability concept by Desurvire et al. [5] can be used to analyze the usability of computer games. Creating the framework is done by summarizing general knowledge about the phenomenon, usually in the form of heuristics that describes important aspects of the subject (see Appendix A for example). Establishing the foundation of the framework is done through different investigations. Such investigations are generally studies performed with usability experts but can also include representative players. A few examples are user testing, focus groups and expert evaluation, as performed by Jegers [10] in his evaluation of the PGM.

2.2.2. The Pervasive GameFlow Model

The model is based on identifying and exploring the most important elements when designing a fun pervasive gaming experience. Introduced by Jegers in his PhD thesis in 2009 [10]. It defines pervasive games as computer games built upon three major aspects:
• Enabling the game to be played at any time or place
• Integrating the physical world as a meaningful part of the game in some way
• Making social interactions a worthwhile option to allow players to collaborate their own game-play

Jegers executed several investigations in his approach to identify and explore the evaluation of pervasive games. His thesis is structured to be a cover paper for five other papers of his making. The testing method executed in this study is based on the last paper presented in his work [9]. In which the PGM elements importance is tested against a game, by playtesting in combination with questionnaire and focus group methods.

2.2.3. Playtesting

The goal of the playtesting method is to gather feedback from actual players. The information is usually used to make decisions about the design of the game that has been tested [19]. Its main element is having players testing a playable version of a design and reporting its experience [6]. Prototype games can have many bugs and unstable mechanics that hinders a consistent testing experience for the players. This is often solved by conducting the tests in a safe, isolated environment. It enables the tests to be maintained and recorded easier. The participating players are selected by the target group of the game and feedback is collected through retrospective interviews or questionnaires but can also be recorded during the play sessions.

2.2.4. Questionnaire

An instrument of research that consists of a collection of questions or statements (see Appendix G for example). It can be used to collect opinions from testers, like retrospective surveys as described by Davis et al. [19]. The advantages of a questionnaire is that its simple to produce and easy to complete for questioners. Since it usually is comprised with predetermined answers.
3. Method

3.1. Game Development

The development of the game to be tested was done in 5 different stages: Design, Functionality, Network, AR and Testing. Each stage was carried out discontinuously during the entire duration of this project with intersecting work in research and testing. Initially, a number of meetings was held to create a common understanding between Tar Valley and the developer. This to ensure that the mechanics of the developed game would be able to represent Tar Valleys vision. Additional meetings was held during the development time so that Tar Valley had opportunities to give feedback in regards to the progress and state of the game.

Design Stage: First a documentation describing the functionality of the game mechanics was produced. This was done by the developer with the information received from the initial meetings with Tar Valley. The core game-play was adapted to fit short playtesting sessions that would allow players to experience most of what the mechanics had to offer. It was also decided that the AR environment would be implemented using marker-based tracking. Because the available testing devices could not support markerless tracking.

Functionality Stage: Game-play mechanics was initially developed for a traditional PC game environment. This was done so that direct feedback could be received very quickly and the developer could gain insight in adapting the mechanics to multiplayer and AR.

Network Stage: After the mechanics had been validated by Tar Valley, a simple implementation of network multiplayer was integrated to the project. It used Unitys built in network API to perform the communication between players phones.

AR Stage: Before implementing the game in AR, a meeting to prioritize game elements was held with Tar Valley. Since this was the last opportunity to make any drastic changes. After a few adjustments in the design, a new prototype was implemented from start. With all game-play in AR and targeted for the testing devices.

Testing Stage: The final part of development was to prepare the game for playtesting. This included a short bug testing procedure where the game was played intensively by the developer and other people at Tar Valley. All unwanted behaviours was reported as bugs to be fixed by the developer before executing the testing method with players. Though the time constraint only allowed some of them to be resolved.
3.2. **GAME DESIGN**

The game focuses on delivering a shared AR experience between two or more players. It takes the form of a simple multiplayer game that two or more people can play together on their smartphones. Players use their phones to perceive a virtual environment aligned on a real physical game board (see Figure 3).

![Image](image1.png)

(a) *Multiple objects from two players*  
(b) *A state with the trap-door open*

**Figure 3:** Two different environment states during game-play with two players

The main action a player can perform is throwing an object. A player can only throw an object on their turn and only once per turn. Therefore players must plan what and where to throw carefully, since there are a limited number of objects that will be thrown per game session. A game session is played out as a match that consists of five rounds. Each player each take turns to throw one object before moving onto the next round. When the fifth round ends, the player with the most valued objects left on the stage wins. During the match, objects thrown by the players can interact with different elements of the augmented environment. Such elements can be buttons, trap doors and moving obstacles.
3.2.1. Game Objects

Objects are colored in accordance with the player that throws it. They are worth different amounts of points and can have other special effects. All objects are affected by gravity and will fall downwards after thrown. Though each objects physical attributes will make each object act different, such as being more bouncy or heavy. The types of objects that have been implemented in the game for testing is the following:

Dice: A small cubic object with six different sides ranging from displaying the numbers 1, 2, 3, 4, 5 and 6. The object is worth as much points as the numbered side facing upwards. It has a very low mass and a bit of bounciness.

Ball: A large, round and heavy object that is worth 5 points. Can be difficult to fit on the board but is hard to move away once positioned. Its major weakness is that it can be destroyed by sharp or pointy objects such as the Dart/Pen.

Dart/Pen: A pointy and long object that can penetrate and get stuck on the board for the duration of the match if thrown correctly. Not worth much points but is hard to move due to its long shape even if not stuck properly.

Poker Chip: A medium sized flat object that does not bounce and is worth 2 points. It is easy to throw and place on the board. If stacked on top of another chip object its points are worth as much as both chips (works retroactively for multiple stacking chips). The chips does not need to be from the same player to activate its effect.

Bomb: A small and round bouncy object that will explode after a short duration. It is not worth any points but the explosion can push other objects out of the board area.

3.2.2. Interface

Players has a simple menu flow for setting up, joining and leaving a game. The main menu consists of one large button 'Start' that when pushed displays the hub for joining or starting games (see Figure 4). Inside the hub menu there are 2 buttons 'Setup' and 'Join' game. Pressing the setup button will create a host game session that other players can join automatically through the join button. The game stops accepting players as soon as the host player presses the 'Start Game' button which starts the game with the currently joined players. Players can at any time disconnect from their current joined game by using the in-game menu.
Players perform the actions in the game by simple touch gestures on their android devices screen. Swiping left or right switches between the different objects available for throwing. Swiping downwards brings up the in-game menu. Touching and dragging upwards charges a throw for the current selected object. During a throw charge an arrow will display the general throw-arc of the object to assist the player (see Figure 5). The player can drag the touch in different directions to change the throw-arc and move the android device to aim the direction in a more direct way. Once the player releases the touch, the object will be thrown.
3.3. User Testing

3.3.1. Preliminary Tests

The test subjects were asked in advance to participate in play-testing for a mobile AR game. They were asked to bring their own smartphones if they could and a time and place was scheduled. The tests began with welcoming the participants and handing out the test forms (see Appendix E, F and G). The participants would then read and fill in the first page (see Appendix E and F). The administrator helped installing the game if needed and made sure everyone was connected to the same network.

Next the test administrator explained the general controls and rules of the game to the players. Then the tracking marker was positioned so the game could begin. The players then proceeded to play the game for about 20 minutes (3-5 matches, depending on how many players was participating in the current test). The test administrator answered questions by the player during active game time regarding the game.
After play, the participants would fill in the form on the backside of the test form (see Appendix G). The test administrator answered questions by the players who had trouble understanding parts of the form. After every player had completed the form, the test administrator would ask and record general feedback regarding the testing method. Lastly the test administrator collected the forms from the players and thanked them for participating. The tests was performed in two groups, one with 2 players and one with 4.

3.3.2. PRIMARY TESTS

Tests was scheduled for 2 testers per test session by contacting the participants and asking if they wanted to partake in testing of a mobile AR game. This produced a time and place that would suit the participating players of the specific session. Tests was also performed in a ‘walk in’ manner. Where the test administrator had a space for performing testing sessions at a school. The test administrator would ask people in the vicinity (mostly students) directly if they wanted to participate in the test and proceed normally when two volunteers had been found.

The test administrator prepared the testing devices before a test session began. This included making sure the devices worked properly and that all surrounding equipment was available. When the testers arrived, the administrator would welcome the participants and hand out the test forms (see Appendix E, F and G). The instructions was explained and the testers was asked to fill in the form on the first page.

After the first form had been filled by both testers, the test administrator would explain the goal and controls of the game for the testers. The information given through the explanation was from a script so that participants across all testing sessions would receive the same instruction. Testers would proceed to play 4 matches, switching devices between each, on the instruction of the administrator.

After the matches was completed, the administrator would stop the playtesting and continue to explain the backside of the testing form to the participants. Testers would then fill out the form (see Appendix G) and be able to give some small feedback. Lastly the test would conclude with the test administrator thanking the testers for participating.
4. Results

The test results has been summarised in Table 1 for the preliminary and in Table 2 for the primary testing methods performed. Each elements questions can be found in the Heuristic Questionnaire Statements (Appendix B) for the preliminary tests, and the primary tests from the modified Post-test Questionnaire (Appendix G). The data from the tests was added together for each question (see Appendix C and D) and divided by the maximum possible value the score could have reached. This was to calculate a simple metric value for analysing the results. Initial values can be found in respective tables appendix. The averaged score is the medium of the possible score outcome. Considered as a complete neutrality answer and has a metric value of 0.60 (3/5).

Each element from the heuristics for the PGM (Appendix A) was represented in two ways in the questionnaires. First with a statement regarding how much the game full-filled the criteria of said statement (question A), and secondly how important the validation of said statement was for the gaming experience (question B). The users could answer in whole integers between 0 to 5. Where 5 would equal total agreement with statement or very important for the gaming experience. 1 would equal total disagreement or not important at all. And 0 would mean the user was unsure or had no opinion in regards to the statement.

<table>
<thead>
<tr>
<th>Element</th>
<th>Question A Score</th>
<th>Question B Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentration</td>
<td>0.73</td>
<td>0.63</td>
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<tr>
<td>Challenge</td>
<td>0.70</td>
<td>0.90</td>
</tr>
<tr>
<td>Player Skills</td>
<td>0.60</td>
<td>0.73</td>
</tr>
<tr>
<td>Control</td>
<td>0.67</td>
<td>0.90</td>
</tr>
<tr>
<td>Clear Goals</td>
<td>0.83</td>
<td>0.73</td>
</tr>
<tr>
<td>Feedback</td>
<td>0.67</td>
<td>0.83</td>
</tr>
<tr>
<td>Immersion</td>
<td>0.83</td>
<td>0.87</td>
</tr>
<tr>
<td>Social Interaction</td>
<td>0.87</td>
<td>0.90</td>
</tr>
</tbody>
</table>

Table 1: Metric results of preliminary test data (Appendix C)
<table>
<thead>
<tr>
<th>Element</th>
<th>Question A Score</th>
<th>Question B Score</th>
</tr>
</thead>
<tbody>
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<td>0.73</td>
</tr>
<tr>
<td>Challenge</td>
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<td>Player Skills</td>
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<td>Control</td>
<td>0.62</td>
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<td>Feedback</td>
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<td>Immersion</td>
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<td>0.73</td>
</tr>
<tr>
<td>Social Interaction</td>
<td>0.83</td>
<td>0.82</td>
</tr>
</tbody>
</table>

Table 2: Metric results of primary test data (Appendix D)

The preliminary tests was performed by a total of 6 players between the age of 21 to 29. Everyone played video games regularly from 4 to 7 to over 20 hours a week on average. There was a mixture of previous AR experience from no experience to accustomed with AR applications. Every participant that played against each other were associates or friends.

The primary tests was performed by a total of 18 testers between the age of 20 to 30. The testers was very mixed in regards to how much video games they played regularly. But most was familiar with AR in some way. Most of the testers that tested against each other were friends or associates.

The most common user feedback recorded during tests was that the controls felt inconsistent and that it was hard to aim in certain situations. Testers also noted that being the last player in a session had significant advantages while few drawbacks. A few would also have liked to see an in-game tutorial or instructions for the game while playing. Tar Valley was very pleased with the game-play of the finished prototype. They agreed with the feedback and proposed to keep developing the project towards a full game in the future. Though they did not find the actual test data to be of much use at the moment, they still showed interest in exploring the use of the method with future testings.
5. Discussion

5.1. Development

Developing a demo game occupied a significant amount of time of the project. This in combination with shaping the testing method and executing the actual tests, resulted in some poor time distributions. To prevent this, some elements in the work could have received more resources such as preparing the testing method. While the game design could have been simplified to meet the deadlines. Adapting the initial project plan more properly when the goal of the project was changed, could certainly have improved the poor time distribution.

5.2. Testing

Some of the primary tests was performed with testers that had played the game in an earlier stage. This could have affected their results since they already had an understanding of the game mechanics. This effect if existing, should be very minor. Since their previous experience was limited and the testing method gave participants a good understanding of the goal and controls of the game. So the difference in previous game experiences would stay more consistent.

It was decided to make a quick analyse of the preliminary tests to adjust any major drawbacks that could be found in the procedure. The executions of those tests was found to possibly provide an inconsistent experience. Not intended to be part of the tests. This because of the varying amount of players that participated in the different sessions and the difference in hardware on players devices. The method was adjusted to have the same amount of players per game session and all testers would use the testing devices provided by the testing administrator. This to make the future primary tests produce more consistent and valuable data.

The results of the preliminary tests and the primary tests will be discussed in separate sections. This to create a better flow of how the actual discussion and analysis took place. The preliminary section is discusses its results isolated from the primary and the primary section discusses its results with some comparisons to the preliminary.
5.2.1. Preliminary Results

The preliminary tests showed that the highest rated elements was social interaction, immersion, and clear goals. While the most important elements was social interaction, control, and challenge. The prominence of social interaction makes this method seem very fitting for this type of game. Since it can be an important aspect of pervasive games. It is worth noting that in the preliminary tests, more players was participating at the same time. Which could have created an external social enjoyment between the players not specifically affected by the game-play.

The other importance of control and challenge might seems opposite to what the initial design is based on. Providing a simple game-play that requires less direct input and focused more on observing. This could be a reflection of the specific testers previous gaming experience. Since all participants in the preliminary tests played games very regularly. It is also worth noting that the changes in design of the game during development, could have shifted the initial concepts direction.

The worst rated elements was player skills, control and feedback. While the least important was concentration, player skills and clear goals. The lack of importance for concentration and player skills could be considered coherent with the concept of the game. But this raises the question if these elements are formatted correctly in the test method. Since it was anticipated that a 'sufficient' amount of concentration would be important. That is, a game that required little concentration. But according to the results this was not the case.

5.2.2. Primary Results

The primary tests showed that the highest rated elements was player skills, clear goals and social interaction. While the most important was feedback, control and, social interaction. Comparing to the preliminary results, an observation can be made to see that social interaction is still one of the highest valued elements. This supports the statement that the testing method is fitting for this type of game, and that the game design should be based on collaboration between players and that it can support it.

Control also remained as an important element. Suggesting that the initial view of the concept could be wrong or that the design decisions has changed aspects of the game-play. One reason could be because the input required by the players is very small. Creating a desire to be in full control of the limited actions that can be performed.
Feedback resulted in being important as well. Which can be a result of a more diverse group of players when it comes to previous gaming experience. Since casual players might be focusing more on observing. Which in conjunction with priority of control, can make the game-play boring or dull when lacking proper feedback for player actions and the environment.

Player skills have been raised from the lowest ranked element to one of the highest. It is difficult to say why this happened in the primary tests, but one reason could be the shifting to a more diverse group of players. The limited preliminary group might have simply been expecting a deeper learning curve. Though they did not find it important. While the diverse group found the mechanics to be more suited for their interest in learning the game. Another aspect that could have caused this is the fact that the game was altered from the feedback in the preliminary tests, and the improvements made the element grade higher.

Control and feedback was the worst rated elements. While challenge, concentration, and immersion was least important. The low rating of control and feedback is most likely caused by the unrefined mechanics that still needed more work to feel satisfying to use. Concentration is once again deemed as not important. Which demands further investigation into if this is a misconception of the concept or if the element needs to be adjusted in the testing method.
6. **Conclusions and Future Work**

The legitimacy of the results and how they can be used to evolve the game design is questionable. It is difficult to use the results to make valid conclusions because of the limitations of the testing method. Jegers primary use of the method this work is based on [9], was to validate the applicability of the PGM. It also produces data for evaluating the importance of the models elements, but it can be difficult to apply when furthering the design of such an early concept as in this work. It would be preferable to evolve the game design by applying additional testing methods based on the PGM.

In terms of evaluating the PGM, this work could be used as a point of reference or maybe the test data used for making comparisons. How usable the results are to further validate the applicability of the PGM is unclear. It could be used to verify that AR games are suitable for the model. While how easy the model is to apply is harder to validate. Since the model was never applied to the game design or used to create a custom testing method.

Regarding the study of how the method can be used in future studies for Tar Valleys game is more positive. Even though the results didn’t necessarily produce conclusive information about design, it did provide an insight in how it could be used to generate usable results. Which indicates that the PGM is a suitable model to base future tests on. The observation that supports this the most is the test results seen in Table 2. Every element of the model was important when comparing to the neutrality score of 0.60. If the outcome would have been reversed (every element being below the neutrality score), it would have suggested the model was not suitable.

Future works of testing would therefore continue to be based on the Pervasive Game-Flow Model. After more research and evaluations of the heuristics and execution procedure. Future testings would also include discussing the results through focus groups with the participating players. To gather more feedback and evaluating the findings of the discussion further.
References

[1] Apple


2004. Using heuristics to evaluate the playability of games.

[6] Federoff, M.
2003. Improving games with user testing: Getting better data earlier.


[8] Google


[10] Jegers, K.


[16] Microsoft

[17] Nielsen, J.

[18] NVIDIA


[21] PTC

[22] Siltanen, S.

[23] Silva, M., R. Roberto, and V. Teichrieb

[24] Starner, T., B. Leibe, B. Singletary, and J. Pair

[25] Sutherland, I. E.

[26] Szalavári, Z., E. Eckstein, and M. Gervautz

[27] Unity Technologies

APPENDICES

APPENDIX A: HEURISTICS FOR THE PERVERSIVE GAMEFLOW MODEL

<table>
<thead>
<tr>
<th>Element</th>
<th>Criteria</th>
</tr>
</thead>
</table>
| **A. Concentration**<br>Games should require concentration and the player should be able to concentrate on the game. | 1) Games should provide a lot of stimuli from different sources  
2) Games must provide stimuli that are worth attending to  
3) Games should quickly grab the players’ attention and maintain their focus throughout the game  
4) Players shouldn’t be burdened with tasks that don’t feel important  
5) Games should have a high workload while still being appropriate for the players’ perceptual, cognitive and memory limits  
6) Players should not be distracted from tasks that they want or need to concentrate on  
7) Pervasive games should support the player in the process of switching concentration between in-game tasks and surrounding factors of importance |
| **B. Challenge**<br>Games should be sufficiently challenging and match the players’ skill level | 8) Challenges in games must match the players’ skill levels  
9) Games should provide different levels of challenge for different players  
10) The level of challenge should increase as the player progress through the game and increases their skill level  
11) Games should provide new challenges at an appropriate pace  
12) Pervasive games should stimulate and support the players in their own creation of game scenarios and pacing |
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<table>
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<tbody>
<tr>
<td>13)</td>
<td>Pervasive games should help the players in keeping a balance in the creation of paths and developments in the game world, but not put too much control or constraints on the pacing and challenge evolving.</td>
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<tr>
<td>14)</td>
<td>Players should experience an appropriate level of challenge set by physical world preconditions (such as distance, location, etc.)</td>
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<tr>
<td><strong>C. Player Skills</strong></td>
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<tr>
<td>Games must support player skill development and mastery</td>
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<td></td>
<td>22)</td>
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<tr>
<td><strong>D. Control</strong></td>
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<tr>
<td>Players should feel a sense of control over their actions in the game</td>
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<td>25)</td>
<td>Players should feel a sense of control over the game shell (starting, stopping, saving etc.)</td>
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<tr>
<td>26)</td>
<td>Players should not be able to make errors that are detrimental to the game and should be supported in recovering from errors</td>
</tr>
<tr>
<td>27)</td>
<td>Players should feel a sense of control and impact onto the game world (like their actions matter and they are shaping the game world)</td>
</tr>
<tr>
<td>28)</td>
<td>Players should feel a sense of control over the actions they take and the strategies that they use and that they are free to play the game the way they want (not simply discovering actions and strategies planned by the game developers)</td>
</tr>
<tr>
<td>29)</td>
<td>Pervasive games should enable the players to easily pick up the game play in a constantly ongoing game and quickly get a picture of the current status in the game world (in order to assess how the state of the game has evolved since the player last visited the game world)</td>
</tr>
<tr>
<td>30)</td>
<td>Pervasive games should provide a flexible interaction style that enables gaming in many possible physical settings</td>
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<tr>
<td>31)</td>
<td>Games should make it hard for players to cheat and uphold the feeling of fairness and equal opportunities for competition</td>
</tr>
<tr>
<td>32)</td>
<td>Pervasive games should be implemented on technological platforms that are easy to use and manage for the players. The games should make use of as few different technological platforms as possible</td>
</tr>
<tr>
<td><strong>E. Clear Goals</strong></td>
<td>Games should provide the player with clear goals at appropriate times</td>
</tr>
<tr>
<td>33)</td>
<td>Overriding goals should be clear and presented early</td>
</tr>
<tr>
<td>34)</td>
<td>Intermediate goals should be clear and presented at appropriate times</td>
</tr>
<tr>
<td>35)</td>
<td>Pervasive games should support the players in forming and communicating their own intermediate goals</td>
</tr>
</tbody>
</table>
| **F. Feedback**  
Players must receive appropriate feedback at appropriate times | 36) Players should receive feedback on progress toward their goals  
37) Players should receive immediate feedback on their actions  
38) Players should always know their status or score |
|---|---|
| **G. Immersion**  
Players should experience deep but effortless involvement in the game | 39) Players should become less aware of their surroundings  
40) Players should become less self-aware and less worried about everyday life or self  
41) Players should experience an altered sense of time  
42) Players should feel viscerally involved in the game  
43) Players should feel emotionally involved in the game  
44) Pervasive games should support a seamless transition between different everyday contexts, and not imply or require player actions that might result in a violation of social norms in everyday contexts  
45) Pervasive games should enable the player to shift focus between the virtual and physical parts of the game world without loosing too much of the feeling of immersion |
| **H. Social Interaction**  
Games should support and create opportunities for social interaction | 46) Games should support competition and cooperation between players  
47) Games should support social interaction between players (chat, etc.)  
48) Games should support social communities inside and outside the game  
49) Pervasive games should support and enable possibilities for game oriented, meaningful and purposeful social interaction within the gaming system  
50) Pervasive games should incorporate triggers and structures (e.g. quests and events, factions, guilds or gangs) that motivate the players to communicate and interact socially |
## Appendix B: Heuristics Questionnaire Statements

<table>
<thead>
<tr>
<th>Element</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Concentration</strong></td>
<td>A) The game required sufficient concentration from the players; the tasks in the game felt important and the game allowed the players to concentrate on them</td>
</tr>
<tr>
<td></td>
<td>B) How important is it for the gaming experience that the game provides what is stated in the former question?</td>
</tr>
<tr>
<td><strong>Challenge</strong></td>
<td>A) The game presented challenges aligned with my abilities as a player</td>
</tr>
<tr>
<td></td>
<td>B) How important is it for the gaming experience that the game provides what is stated in the former question?</td>
</tr>
<tr>
<td><strong>Player Skills</strong></td>
<td>A) The game provided good support for the player to develop the abilities needed in order to play the game in a satisfying way; it was easy to learn the game and easy to find help when needed</td>
</tr>
<tr>
<td></td>
<td>B) How important is it for the gaming experience that the game provides what is stated in the former question?</td>
</tr>
<tr>
<td><strong>Control</strong></td>
<td>A) The game gave me a sense of control of my actions in the game</td>
</tr>
<tr>
<td></td>
<td>B) How important is it for the gaming experience that the game provides what is stated in the former question?</td>
</tr>
<tr>
<td><strong>Clear Goals</strong></td>
<td>A) The game presented clear goals to strive for at all times</td>
</tr>
<tr>
<td></td>
<td>B) How important is it for the gaming experience that the game provides what is stated in the former question?</td>
</tr>
<tr>
<td><strong>Feedback</strong></td>
<td>A) The game gave me sufficient and useful feedback on my actions in the game, at times when I felt it was motivated</td>
</tr>
<tr>
<td></td>
<td>B) How important is it for the gaming experience that the game provides what is stated in the former question?</td>
</tr>
<tr>
<td><strong>Immersion</strong></td>
<td>A) The game evoked a sense of being deeply involved in the game and the game world</td>
</tr>
<tr>
<td></td>
<td>B) How important is it for the gaming experience that the game provides what is stated in the former question?</td>
</tr>
<tr>
<td><strong>Social Interaction</strong></td>
<td>A) The game gave me opportunities to interact with other players and a good support for collaboration in different ways</td>
</tr>
<tr>
<td></td>
<td>B) How important is it for the gaming experience that the game provides what is stated in the former question?</td>
</tr>
</tbody>
</table>
APPENDIX C : PRELIMINARY TEST DATA

Number of Participants: 6
Ages: 21 to 29 (average 24)
Sexes: 6 Males

Average hours per week participants played video games:
2 played between 4 to 7 hours
1 played between 7 to 12 hours
2 played between 12 to 20 hours
1 played more than 20 hours

Participants previous experience with AR:
1 had no knowledge or experience whatsoever
1 was familiar with the term but had no experience
3 had some previous experience with AR
1 was accustomed to how AR applications are usually played/used

<table>
<thead>
<tr>
<th>Element</th>
<th>Question A Score</th>
<th>Question B Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentration</td>
<td>22 / 30</td>
<td>19 / 30</td>
</tr>
<tr>
<td>Challenge</td>
<td>21 / 30</td>
<td>27 / 30</td>
</tr>
<tr>
<td>Player Skills</td>
<td>18 / 30</td>
<td>22 / 30</td>
</tr>
<tr>
<td>Control</td>
<td>20 / 30</td>
<td>27 / 30</td>
</tr>
<tr>
<td>Clear Goals</td>
<td>25 / 30</td>
<td>22 / 30</td>
</tr>
<tr>
<td>Feedback</td>
<td>20 / 30</td>
<td>25 / 30</td>
</tr>
<tr>
<td>Immersion</td>
<td>25 / 30</td>
<td>26 / 30</td>
</tr>
<tr>
<td>Social Interaction</td>
<td>26 / 30</td>
<td>27 / 30</td>
</tr>
</tbody>
</table>
Appendix D: Primary Test Data

Number of Participants: 18
Ages: 20 to 30 (average 24.61)
Sexes: 14 Males, 4 Females

Average hours per week participants played video games:
2 played less than 1 hours
2 played between 1 to 2 hours
2 played between 2 to 4 hours
2 played between 4 to 7 hours
4 played between 7 to 12 hours
4 played between 12 to 20 hours
2 played more than 20 hours

Participants previous experience with AR:
1 had no knowledge or experience whatsoever
4 was familiar with the term but had no experience
10 had some previous experience with AR
3 was accustomed to how AR applications are usually played/used

<table>
<thead>
<tr>
<th>Element</th>
<th>Question A Score</th>
<th>Question B Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentration</td>
<td>69 / 90</td>
<td>66 / 90</td>
</tr>
<tr>
<td>Challenge</td>
<td>69 / 90</td>
<td>65 / 90</td>
</tr>
<tr>
<td>Player Skills</td>
<td>76 / 90</td>
<td>72 / 90</td>
</tr>
<tr>
<td>Control</td>
<td>56 / 90</td>
<td>75 / 90</td>
</tr>
<tr>
<td>Clear Goals</td>
<td>76 / 90</td>
<td>71 / 90</td>
</tr>
<tr>
<td>Feedback</td>
<td>60 / 90</td>
<td>76 / 90</td>
</tr>
<tr>
<td>Immersion</td>
<td>69 / 90</td>
<td>66 / 90</td>
</tr>
<tr>
<td>Social Interaction</td>
<td>75 / 90</td>
<td>74 / 90</td>
</tr>
</tbody>
</table>
APPENDIX E: INSTRUCTIONS

1. Pretest Questionnaire
Fill in the Pretest Questionnaire form on this page.

2. Testing
Follow the instructions from the test administrator to start testing the game.

3. Post-test Questionnaire
Fill in the Post-test Questionnaire form on the next page. The form consists of multiple statements regarding player experience for the game you just played. Your objective is to give each statement a rating from 1 to 5 based on how much you agreed with the statement. 1 equals total disagreement and 5 equals total agreement and no mark means unsure or no opinion.

Feel free to ask the test administrator if you are unsure of anything during the testing.

APPENDIX F: PRETEST QUESTIONNAIRE

Age: [ ] years

Sex:
[ ] Male
[ ] Female

How many hours per week on average do you play video games?
[ ] Less than 1 hours
[ ] Between 1 to 2 hours
[ ] Between 2 to 4 hours
[ ] Between 4 to 7 hours
[ ] Between 7 to 12 hours
[ ] Between 12 to 20 hours
[ ] More than 20 hours

How much previous experience do you have with augmented reality (AR)?
[ ] No knowledge or experience whatsoever
[ ] Familiar with the term but has no experience
[ ] Some previous experience with AR
[ ] Accustomed to how AR applications are usually played/used
### Appendix G: Post-test Questionnaire

<table>
<thead>
<tr>
<th>Statement</th>
<th>1</th>
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<tbody>
<tr>
<td>The game required sufficient concentration from the players; the tasks in the game felt important and the game allowed the players to concentrate on them</td>
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<td>The game presented challenges aligned with my abilities as a player</td>
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<td>The game provided good support for the player to develop the abilities needed in order to play the game in a satisfying way; it was easy to learn the game</td>
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<td>How important is it for the gaming experience that the game provides what is stated in the former question?</td>
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<td>The game gave me a sense of control of my actions in the game</td>
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<tr>
<td>The game gave me sufficient and useful feedback on my actions in the game, at times when I felt it was necessary</td>
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<tr>
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<tr>
<td>The game made the player feel a sense of being deeply involved in the game and the game world</td>
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<tr>
<td>How important is it for the gaming experience that the game provides what is stated in the former question?</td>
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<td>The game gave me opportunities to interact with other players and a good support for playing together in different ways</td>
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