A Comparison of Interface Approaches for Immersive Pervasive Games

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Abstract

The aim of this thesis is to compare two different interface approaches for pervasive games with a focus on immersion. We designed and created two small pervasive games and implemented both on two different platforms; smartphone and wearable device. We created four pervasive game prototypes which we tested with a group of fourteen testers. We subsequently conducted interviews using the Repertory Grid Technique. The findings suggest that our testers appreciated wearable devices more than smartphones in the context of immersion, while they identified characteristics they associated with each platform; Smartphones were considered familiar, inconspicuous, casual but not very exciting. Wearables were considered a new experience and fun but also strange and attention-drawing.

Keywords: pervasive games, ubiquitous games, immersion, wearables, touchscreen, tactile, repertory grid technique
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1. Introduction

In this thesis, we describe the design, implementation and testing of two pervasive games. Play is a universal part of the human experience, which has been the focus of research since Huiziniga's seminal book “Homo Ludens” which was published in 1949 [1], and still attracts researchers to this day [2][3]. People around the world spend more and more in games [4] attracting the interest of both investors and academics. In this thesis we use the term “immersive games” meaning games that promote immersion in their game-world, and more specifically imaginative immersion, as it was described by Ermi and Mäyrä[5]. Imaginative immersion is a feature of games that focus on the storyline and specific characters, leading players to identify with them.

Pervasive computing, which has its roots in Weiser’s vision of calm computing [6], describes computers that will help humans without distracting them, by blending seamlessly into the background environment, providing assistance when needed. Based on this concept, pervasive games are defined as games that are played in the real, ordinary world and are not confined in computer screens [6]. Pervasive games differ from other types of games because they offer a unique blend of real life and game activity, a feature that many players appreciate [8][9]. Pervasive games have become more common with the advent of the smartphones, which seem to be ideally suited for such applications, as they have the hardware required and are usually carried by their users throughout the day.

Wearable computing devices form a different category of gadgets that are becoming increasingly more prevalent in our daily lives[10]. Commercial applications of these devices became popular recently due to the quantified self movement which is part of the trend towards the Internet of Things [11]. From being used as simple fitness gadgets, usually paired with smartphones, wearable devices and especially smartwatches are becoming increasingly complex offering more processing power, sensors and a screen space. While wearables have only recently captured the spotlight by becoming commercially available, as a topic they have been studied by researchers from as early as 1945[12].

The field of pervasive games is being explored, in recent years, by a number of researchers who follow different approaches depending on the specific subtopic they study[13][14][15]. Generally, there is a tendency to use smartphones as the medium through which the user plays the game[16]. However, relating pervasive games to wearable devices is less common. We believe that employing smartphones as the interface in pervasive games comes at the cost of immersion, as it disconnects the users from their environment, and breaks the “magic circle” of the game, as according to Nieuwdorp [17] the interface does not exist just on the screen but also in the player’s mind.

In this thesis we examine the hypothesis that wearable devices provide a better interface for immersive pervasive games, than smartphones do. In order to investigate the research questions we designed, implemented and tested two small pervasive
games, in two versions each. One facilitated through a smartphone and one facilitated through a wearable device.

1.1. Goals

This thesis presents a comparative study between four implementations of pervasive games – two for smartphones and two for wearable computing devices. The core research interest in this comparison lies in exploring the inherent qualities of the mobile platforms to support immersive end-user experiences.

In order to achieve this, we focus on two research questions: (1) How does the type of mobile platform itself affect the perceived immersion? And (2) what specific benefits and challenges may be identified for smartphones and wearable computing devices in the context of pervasive games?

By perceived immersion we mean immersion as it is perceived not by the researcher, who has the role of the observer, but as it is perceived by the players themselves.

1.2. Approach

Towards answering the research questions we designed, implemented and tested two different pervasive games using both approaches with each, smartphone and wearable, and tested them with potential users. We then conducted interviews with these testers using the Repertory Grid Technique to draw conclusions, as interviews are considered an appropriate research method that does not affect the gameplay experience and can capture the immersion aspect [18], which can be difficult to define.

The first game concept is based on the popular mechanics of treasure hunts where the players have to physically visit specific locations to uncover clues or prizes. Having the players navigate the real world to progress in the digital games ties the game-world with reality providing the player with a pervasive experience.

The second game concept is based on memory games and more specifically on the game Simon Says, where players need to memorize and repeat a pattern that becomes progressively longer and harder to remember.

2. Literature Review

Our literature review aims to explore the field of pervasive games, focusing on different challenges they present to their designers. Our aim is to gather guidelines and suggestions from the literature in order to create pervasive games focusing on immersion. The articles were selected following the seven step approach for literature reviews suggested by Oates[19], searching, obtaining, assessing, reading, critically evaluating and finally writing a critical review of each article.

First, we investigate the terminology of pervasive games to provide the basis for the rest of our work. Next, we research pervasive game design and interfaces, and
afterwards we focus on ways to provide immersion to a pervasive game, through adopting features of Live Action Roleplay Games. Finally, we investigate some of the issues one should be aware of when implementing a pervasive game and the gameflow model of player enjoyment.

2.1. Theoretical Background and Terminology

We believe that when approaching a new field, a researcher's first step should be to become familiar with its terminology and different sub-sections. As technological terms, or terms used in the context of technology can be ambiguous, we value the first paper reviewed due to the clarification it provides, and intend to use its terminology in future work. Hinske et al. regard different approaches in defining the components Pervasive Games consist of, their relation to playing and games in general, and how the various terms and views can be integrated [20]. To analyze the term “Pervasive Game”, the authors investigate the definitions of the words \textit{game} and \textit{pervasive} extensively, analyzing them into components. Pervasive Games are thus defined as “\textit{a ludic form of mixed reality entertainment with goals, rules, competition, and attacks, based on the utilization of Mobile Computing and/or Pervasive Computing technologies}”. The specific elements pervasive games consist of are analyzed further and are investigated in the context of the four different dimensions that contribute to the gameplay experience: physical experience or challenge, mental experience or challenge, social experience and immersion. Finally, guidelines for pervasive game design are provided, based on their different elements that constitute them: rules, competition, goals, outcome, decisions and emotional attachment.

An overview of the evolution of the field of pervasive games is provided by Magerkurth et al. [8]. Before computers, games employed physical locations and tangible items. The other main element they tapped into, were the face to face interactions happening between the players. These interactions were arguably the factor that made games interesting. With the introduction of computer games, the focus of the players shifted gradually to the screen as well as the means of playing the games. Videogames were very appealing and popular because, through using graphics on a screen, they provided increased immersion into the game world. However, the interactions between players suffered as when available, they were constricted by the means provided by the game. Physical interactions were also minimized to those required to operate the game controllers [20]. Today, there is a growing trend of reclaiming the lost physical aspect of games, through Pervasive Games. Pervasive games do not take place strictly in the digital space but aim towards blending the digital aspect with real-world physical and social interactions.

Nieuwdorp investigates this unique blend of the real and the physical and in the context of interface in pervasive games, stating that the term does not reside just in physical elements like the screen but also, in the case of pervasive games, in the mind of the players [17]. As the virtual and physical worlds converge, their semiotics are mixed requiring an investigation of the interface from a cultural standpoint. The author names
the mental shift between the two worlds *liminal interface* and describes it as “the edge of the magic circle”. Liminal interface is distinguished into two levels: the paratelic interface where the real world is left behind and the paraludic interface where the player accepts the conventions that exist in the game world. The unique approach of this theoretical paper makes it particularly interesting, as the concepts and terminology introduced are not encountered often in the field. Defining the interface as something that takes place in one’s mind as well as in the physical world, and investigating the way the players distinguish the virtual from the real in pervasive games, are in our opinion interesting concepts to ponder when designing such applications where immersion in the game world is important.

2.2. Pervasive Game Design

Designing pervasive games presents a number of challenges, some of which may be different from the ones game designers usually face. Bertelsmeyer et al. focus on pervasive game conceptualization and design [21]. The authors discuss the different concepts they pursued, when tasked with creating a wearable game, and describe their thinking process and the reasoning behind their decision making. The authors gleaned the game requirements from tests conducted with two different game prototypes, and also from the limitations of technology available at that time. The final game concept to be developed was based on the real-time strategy game genre having players collecting resources, building and defending bases and exploring the map that is the game area. Today, a number of the technological limitations faced by the authors have been overcome. The relevant part of the paper is the authors’ considerations regarding player expectations when they first approach a pervasive game, often expecting it to be similar to a computer game. Another thing to consider is that when players need to use physical skills, the game can be skewed in favor of the physically stronger players as happens in sports. Korhonen et al. also present challenges that game designers may face when designing pervasive games, and suggest ways to overcome them[15]. They created an experimental multiplayer pervasive mobile game in order to conduct a user study, resulting in these design issues. The game employed three types of contextual information in it: environmental, space and time, and proximity to others. Other features included asynchronous slow updates, allowing for play regardless of place and allowing communication with others, without disturbing the gameplay. The study’s results indicated that the game sessions should be adjustable depending on the player’s schedule and, when offline, communication outside the game is required. Also, using contextual information is important so the designers need to make certain that players have a common understanding of the current context. Finally, all players need to have equal chances to progress in the game which may mean access to relevant contextual information. We believe that the guidelines provided, as well as the structure of the mobile game created, can be useful when designing mobile pervasive games. A different kind of design challenge for pervasive games has to do with the clash of the rules
enforced by the “magic circle” of the game, with the social rules of the real world. This is the topic of Linehan's work [22]. By participating in a game, the players agree to follow the game's rules for its duration. As pervasive games are played in real world environments interesting situations may arise when the game's rules conflict with the social rules accepted in a specific place or situation. The author explores what may happen in such situations by creating and testing a game designed to challenge the social rules associated with libraries. The game requires its players to make loud noises while in libraries. The louder the noise the higher the score the player gets. After its implementation, the players were interviewed about their experience. While all of the players were reluctant to break the social rules, all but one managed to actively participate. Most attempted to compromise by making loud noises that are socially acceptable, such as coughing while others got more creative and some cheated preferring to break the game rules than the social ones. The authors conclude that the dilemma posed by the game, made it fun, however designers of similar games should take care, as they should promote mischief behavior and not anti-social behavior. As our game may also challenge social rules by alternating the players' behavior from the norm, we intend to take special care so as to avoid any form of anti-social behavior.

2.3. Immersion

Immersion is a feature we are particularly interested in investigating and implementing in our game. Related to this topic, Balllagas et al. conducted a formative evaluation of the design of REXplorer, a mobile pervasive serious game designed for immersion, aimed at tourists visiting Regensburg in Germany [14]. The game attempts to combine education and entertainment and is realized through a wand, which is a mobile phone device placed in a casing. It sends the players on a tour of local sites by employing fictional characters who assign them quests, leading them to different historical locations. The game was evaluated through an interactive play session followed by a focus group interview, both of which were recorded. The results showed that despite the purposefully basic visuals, in some cases the device became the focus of attention, to the point of causing players to put themselves in danger by wandering into construction sites and traffic. Players reported they enjoyed the non-linearity of the game, while performing gestures with the device in public made some uncomfortable, and in one case caused a minor accident by distracting a driver who was driving by. This qualitative data was used to inform the game design and should be considered when designing pervasive games, meant to be played in public, as too much immersion may cause problems in the real world.

Considering high immersion, Live Action Roleplaying Games (LARPs) and specifically the nordic style of LARPing are recognized as being most immersive for their players. LARPs are a kind of role-playing games in which participants act out scenarios physically, often using costumes and props. Once a nordic style LARP game starts, it is not allowed to switch back to real-world interactions before the game ends, so as to protect the perceived authenticity of the experience. Waern et al. discuss Live Action
Role Play (LARP), and how it can inform the design of pervasive games, in order to provide an immersive game play experience [23]. Anything that has no place in the game-world is hidden away for the duration of the game. If a specific piece of technology such as a digital device has to be used in the game, then it is written into the game scenario along with its specific features and what they mean in the game world. An example provided is the case of the pervasive game Treasure [24], where the seams between different Wi-Fi areas in the game zone where integrated into the game instead of being disguised. The authors conclude that in games striving for immersion, the role of technology is different, as it is not just used to realize the game but it also becomes a stage prop within the game. The guidelines given in this paper are very useful to us, as we intend to develop a highly immersive game. A report of lessons learned from designing and carrying out a LARP-style pervasive game is provided by Jonsson et al. who created “Prosopopeia Bardo 1: Där vi föll” as proof of concept [25]. In it, players were assigned characters and had to solve a number of puzzles, interact with people inside and outside the game, use different devices and visit different physical locations. The game was evaluated using a mix of qualitative and quantitative approaches. The players were monitored through web cameras at fixed locations and their communications were recorded. Also, one of the players was tasked with taking notes of the entire game producing a type of ethnographic report. After the game ended, a wrap up session was arranged and a follow-up online questionnaire was sent to the players. Finally, there were follow-up interviews and discussions were the participants provided more feedback. The authors concluded that interacting with non-players can be an issue for the players. Immersion was reduced due to the game taking place in the mundane world, having to use real skills to solve in-game puzzles and having a pressing time schedule. The technology used was appreciated to the extent that it provided play opportunities. The video data collected was not used due to size and the fact that the players spent the most time in areas without cameras. This article is interesting not only because of its results, but also due to the different evaluation methods used.

Another kind of immersion is ectodiegetic immersion, which is immersion contributed to a pervasive game experience from environmental factors. This subject, with regards to pervasive games is explored by Oliveira et al. [18]. Ectodiegetics influence the game though unlike intradiegetics they do not reside within a pervasive game's main narrative, but in its spatial and temporal environment. The authors tested this assumption by conducting interviews with nine pervasive game players and concluded that ectodiegetic elements may indeed corroborate the player’s immersion. Despite the facts that the interviewees were rather few and that most of them had significant experience with pervasive games, having designed pervasive games themselves, we believe that there is merit to this paper’s conclusions. As pervasive games are played in the real world it seems logical that they are affected by real world situations that cannot be anticipated. An example of this, described in the paper, was playing the game at the local university campus with the area being empty due to a strike, thus leading to a more immersive experience. As such ectodiegetic factors cannot
be anticipated there is little that can be done about them during the game design phase. However, it is useful to recognize them during the game evaluation as circumstances may have skewed the collected data and therefore our conclusions about a pervasive game.

2.4 Gameflow

Gameflow is a model for evaluating player enjoyment first presented by Sweetser and Wyeth [26], based on flow, a popular model of enjoyment developed by Csikszentmihalyi [27]. Game flow consists of eight elements – concentration, challenge, skills, control, clear goals, feedback, immersion, and social interaction. Every element includes a set of criteria for achieving enjoyment in a game. We think the concept of gameflow is an interesting topic in the context of this thesis, especially since immersion is our focus area. However, the gameflow model was designed with traditional games in mind. As pervasive games have important differences to other games, it is crucial to examine how these differences may affect gameflow as it was described in the previous paper. The topic of game flow with regards to pervasive games is discussed by Jegers [28], who identifies three main features that either alone or in combinations set pervasive games apart from other games: mobile/place-independent gameplay, social interaction between players, and integration of the physical and virtual worlds. Taking these into account, a modified pervasive game flow model is suggested and guidelines are provided in the form of criteria. We believe that some of these criteria are only relevant to some pervasive games and not others as not all such games function in the same way. For example the criterion “Pervasive games should support and enable possibilities for game oriented, meaningful and purposeful social interaction within the gaming system” only applies to pervasive games that feature multiplayer modes. We have distinguished some among the other suggestions, which we believe are fitting, and intend to follow them in our game design. These include simplifying the process of switching attention from the game-tasks to the real world without losing the feeling of immersion, supporting the formulation of intermediate goals and scaling difficulty as the game progresses.

3. Research Approach

The research approach used in this thesis is comprised of four strategies that address and support the four main steps of this study. An overview of the strategies used can be seen in Table 1.

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Table 1: Research Strategy per Thesis section
3.1 Literature Review

We used the *Literature Review* method[19] to explore the academic works that form the background of our research. To conduct the literature review we followed the suggestions made by Oates[19], separating our topic into keywords which were then used in different combinations to make queries on the Google Scholar search engine, the Malmö University Library, as well as other established online sources for academic works such as ACM and IEEE. For the subtopics most related to technologies, we primarily focused on the most recent academic works in order to safeguard the relevance of this thesis by keeping it up to date as possible. The keywords we used include but are not limited to: pervasive games, ubiquitous games, repertory grid, wearable games, immersion, immersive games, flow and gameflow. Writing the literature review was an iterative process as proposed by Dawson[30]. The first iteration took place at the start of this work to provide a general background and more articles were reviewed and added in this segment as required by the process of this thesis, in order to cover new topics and sub-topics we come across.

3.2 Design And Create

Answering the research questions of this thesis requires us to compare pervasive game prototypes, therefore the main research strategy used is one that leads to producing these digital artefacts. To make the pervasive games we used the *Design and Create* strategy which is also described by Oates[19]. Each of the two games were implemented in two versions featuring different interfaces: one on a wearable device and one on a smartphone.

To design the game prototypes we used an adaptation of the Game Design Document found in Fullerton's *Game Design Workshop*[29], which we believe is a good way to document the specifics of each game in a structured form, such as game mechanics, components and plot.

To implement the smartphone app version of the game prototypes we used MIT's Appinventor[44] which is a tool that enables rapid prototyping for Android applications. We used the Arduino platform[45] for creating the wearable versions of the prototypes. Both development solutions were chosen due to their capacity for rapid prototyping which was required by the timeframe of this thesis.

3.3 Repertory Grid Technique

Once the four IT artefacts we aimed to evaluate in this thesis were developed, we had them tested by testers which we subsequently interviewed. To elicit the testers' unbiased opinions of the artefacts, we held structured interviews using the Repertory Grid Technique. The Repertory Grid Technique (RGT) is more related to grounded theory and interpretive research than the positivist approaches that are usually employed in computer science[32]. It has its roots in Personal Construct Psychology which dictates that people understand things by placing them in similarity-difference dimensions, which are called *Personal Constructs*. The personal constructs form the lens through
which a person views the world. These are subject to change as the person experiences new things. Since its inception by clinical psychologist George Kelly in 1955[34] RGT has been adopted as a method for eliciting unbiased opinions from groups of people[33] in a number of different fields such as marketing and counseling, as well as in academia and computer science in particular[32].

As this thesis is concerned with the difficult to define concept of immersion, personal preferences and the reasons behind them, we feel that RGT is indeed a good research strategy that can provide us with unbiased but also useful data. Below we provide an overview of the RGT’s components.

Repertory Grids consist of three parts: Elements, Constructs and Links. Elements are specific instances of the topic studied. If for example the topic is computer Operating Systems then the elements could be Microsoft Windows 8, Microsoft Windows 7, Mac Osx 10.9, Mac Osx 10.8 and Ubuntu 14.04 LTS. Constructs are the scales used by the participant to rate the Elements. Each construct scales between two opposite extremes for example Boring - Interesting or Bad – Good. Once the Elements and the Constructs have been settled, they are used to form a table which is then filled in by the participant, providing the researcher with the Links between the Elements and the Constructs.

The scales used to rank the constructs are usually odd numbered so as to provide the interviewees with the option of not leaning towards one of the construct poles. Common sizes of scales are 1 to 5 or 1 to 7 if more detail is required. In this thesis we have decided to use scales of 1 to 5 as we feel these capture enough detail for our scope.

Links can be analyzed statistically and/or semantically to yield meaningful results. Below we present a repertory grid we created during our data collection as an example.

![Figure 1: A Repertory Grid example](image-url)

There exist different types of RGTs depending on whether the Elements used are selected and provided by the researcher or elicited from the participants. There is also a
similar distinction but depend on how the Constructs are selected. Each of the different types of RGT has its own positive and negative aspects and can be more or less appropriate to a specific type of research, as they balance participant freedom and research control in different ways.

The main RGT types are:

1. **Full RGTs**: Participants identify both elements and constructs. This approach yields rich data but makes comparisons between participants' grids difficult.

2. **Partial RGTs**: Participants have to build constructs about a set of elements supplied by the researcher.

3. **Fixed RGTs**: Participants rate provided elements using provided constructs, both of which are familiar to the participant and deemed representative of a population by the researcher.

In this thesis we followed a mixed approach. We provided the participants with the elements to be evaluated and had them identify most of the constructs themselves. We used five elements: the four pervasive game artefacts the testers played, plus a fifth element we named “Ideal pervasive game”. We added this fifth element to help us draw conclusions regarding the testers’ preferences for each construct, as this element was ranked in the ideal position for every construct according to the testers’ personal viewpoints.

We elicited constructs from the testers and afterwards supplied them with two more fixed constructs regarding the topic of immersion. This approach provided our testers with freedom while it ensured that we would get the needed data to answer our research questions. Regarding the supplied constructs, the participants were instructed to disregard any construct they did not understand or thought did not apply to the given elements, so as to avoid getting meaningless data. None of the testers had trouble associating the supplied constructs to the elements and so they all ranked them normally. The supplied constructs were focused on the topic of immersion specifically. To create these we conducted an online thesaurus search looking for synonyms and antonyms of the word “immersive” [36]. We thereby concluded on the following constructs:

- Absorbing – Uninteresting
- Engaging – Boring

### 3.4 Data Collection

We aimed for the participant group to be comprised of a minimum of twelve testers, as according to Tan and Hunter this is a sufficient sample size to elicit constructs that can adequately describe a set of elements [31] The interview process was
structured following the Repertory Grid Technique approach, having the testers elicit constructs of their own regarding the games they played and evaluate them on both those elicited constructs, as well as on the two fixed constructs we provided.

By the end of testing we had interviewed a total of 14 testers, 7 men and 7 women, of ages between 22 and 36. The 14 testers played the games in pairs, making sure that each of them used both the wearable and smartphone iterations of both games, and were subsequently interviewed in pairs as well. Any disagreements that came up regarding the ranking of the elements were recorded and taken into consideration. A full list of the testers is available in Appendix C at the end of this thesis. Testers were selected based on availability, proximity and interest in the research as we wanted to lower the tester mortality rate. We gathered our first testers from our acquaintances and used snowballing[19] asking these trusted testers to suggest others until we reached the total of fourteen testers. The testing and the interviewing sessions took place over a period of four days.

3.5 Data Analysis

The data collected through the RGT is in the form of seven completed grids/matrices. Eliciting constructs from each individual group of testers is a good solution as otherwise the constructs have to be provided to the participants, limiting the interviewees’ freedom and possibly yielding poor results or they would have to be elicited in a meeting with the entire group of testers which would be difficult to arrange and manage.

There exist a few different techniques which can be used to analyze this data, depending on the kind of results the researcher is looking to acquire. These include frequency counts, content analysis, visual focusing, and statistical analysis. To answer our research questions we used a combination of different techniques.

To answer our first research question, we combined the 14 fixed constructs into a single merged construct, using the median values of the original group of constructs. This method was used by Fallman [37] and has the advantage of minimizing the effect isolated extreme values have on the outcome, compared to using the average values. We then plotted this construct to detect where each element is situated with regards to the axes and the other elements.

To answer our second research question, we processed the elicited constructs. We identified eight different groups of constructs on different topics by semantic analysis, and combined them into single constructs containing the meaning of their original constructs, as we did for the fixed constructs. We again used the median values of the original constructs to rank the elements on the new constructs. After this process we were left with a total of 28 constructs, which we proceeded to map with PRINCOM mapping in order to identify which elements were better associated with which construct poles. Finally, we generated a table containing the percentage of matching between the different elements to verify how the different pervasive game iterations ranked compared to each other and the ideal pervasive game.
**PRINCOM mapping**

PRINCOM mapping [38] is a visualization method that helps identify which sets of constructs better characterize each element, and therefore which characteristics are the causes of possible similarities between the elements. In it, the repertory grid is treated as if the elements are points in a n-dimensional space which is defined by the constructs, centered on the elements’ means. Each construct is displayed as a vector describing a particular dimension of the elements being compared. These vectors may be analyzed mathematically, but are usually represented visually in PRINCOM maps instead. The data (vectors) is rotated through principal component analysis, around the center point which is the mean point of all vectors, so as to spread the elements out as much as possible in a 2-dimensional plot [38][39].

The point of using this method, is to visualize the repertory grid in two dimensions, without sacrificing large amounts of the original data, so as to draw valid conclusions from the relative positions of the *Elements to the Construct poles* and of the *Elements between them*. The construct poles nearer to an Element can be considered the ones that characterize it the best. We should also note that while the distance between different poles may indicate a similarities between them, that is not always the case and semantic interpretations are often used to verify such indications. In our analysis we *do not* take into consideration the positions of the construct poles to each other.

An example of a PRINCOM map can be seen in Figure 2 below. This visualization was created from the elicited constructs of tester Group 4, therefore the data presented here does not represent our final results which also take in account six more groups of testers.

*Figure 2: Example PRINCOM map*
In a PRINCOM map the axes represent the principal components and are used to select which components are plotted on the horizontal and vertical axes. The X-axis is chosen because it captures the highest percentage of the variance, the Y-axis the second highest percentage of the variance and so on. In Figure 2 we see that the X-axis accounts for 59.9% of the variance, the Y-axis for 30.3% of the variance and the Z-axis for 8.6% of the variance. The goal here is to present as much of the variance as possible in the first three axis. For the scope of this thesis we consider a total of 85% variance in the first three axis to be sufficient.

A PRINCOM map can be interpreted as showing which poles of the constructs are most closely related to each element. For examples such an analysis of Figure 2 would inform us that among other things, the Ideal game uses more clues and has an open time limit, the wearable version of Game 2 stands out, while the wearable version of Game 2 has a specific time limit and uses a single source of clues.

More information on PRINCOM mapping as well as a discussion of this and other ways of analyzing and visualizing repertory grid data can be found in the works of Gaines & Shaw [40][41].

4. Game Design and Implementation

In this chapter we present the design process and implementations of the game prototypes we created in detail. For each of the two games we provide a game design document, which contains all relevant information about each game for both of its implementations. The "Development Platform and Tools" section of each of the design documents addresses how the wearable prototype was created, as well as what tools were used to develop the mobile application versions of the games.

The games' aim is to implement specific game interactions/mechanics, in order for them to be tested with the two platforms this thesis is concerned with; the mobile phone device and the wearable device. As a subject, game mechanics have caused debates among academics and game theorists and there is yet no single definition of them that everyone agrees upon. It is not our intention to take sides in this debate, so in this paper we simply adopt Sicart’s definition [43] of game mechanics as “methods invoked by agents, designed for interaction with the game state” in order to appropriately describe what happens in the games we designed. As pervasive games take place in the real world as well as in the game-world, mechanics can include methods or actions in the virtual world as well as in the real world.

The games were purposefully designed to be small in order to highlight the devices that run the games as well as make possible faster testing cycles. The game plots and mechanics were selected with the feature of immersion in mind.

To provide a comprehensive outline of the games we created and their specific features, we have chosen to use an adaptation of the Game Design Document as suggested by Fullerton[29] for each of the two games designed, which follows in the next two sections. Certain part of the generic Game Design Document template such as
Marketing, Sales Expectations and Legal Analysis, have been removed as they do not apply in our case. Others have been merged to better suit the context of the games. Sections 4.1 and 4.2 contain the adapted game design documents for our two games: Spy Hunt and Simon Says.

### 4.1 Game 1: Spy Hunt

#### 4.1.1 Gameplay synopsis

This is a pervasive game based on the familiar game concept of *treasure hunts*, where the players have to search the world around them for clues in order to progress and eventually beat the game. Players take on the role of spies, tasked with stopping a terrorist attack by following clues which will help them discover how, where and when it is going to happen.

The players start at a café at a central location of the city where they are looking for a missing colleague. Looking at the stop were the missing agent left “dead drops” in the past, they find a bag containing a smartphone a letter and a map of the city with three different locations marked on it. The letter’s aim is to explain the situation to the players, further introduce them to the story and help facilitate immersion. It is written by a fellow spy in first person and is directed at the players guiding them to visit the locations marked on the map and use an application on the smartphone named Decoder. Doing this will allow them to intercept transmissions between members of the terrorist group, providing them with the required clues.

When the players are not near one of the spots marked on the map the smartphone application reads "NO TRANSMISSIONS" in a red font. When they get near to one of the locations, the text changes to "TRANSMISSION DETECTED" in a green font and a number of knobs become visible, depending on the location. The players get a chance to decode the incoming transmission by turning these virtual knobs. When all knobs are in the right position a clue is presented in the form of a word. After collecting all the words from the map location the players will have the needed information for the first part of the game. At this point a stranger presents himself and gives them another paper bag containing a letter from their Headquarters, a wearable device and another map of the area with three new locations marked in it. This starts the second part of the game, which has identical mechanics to the first part but takes the story further while the players have to uncover clues using the wearable device instead of the smartphone.

Below we see mock-ups of the smartphone application's interface. The first screen is what the players see when not near a game location. The second screen appears once they enter such an area and the third once they successfully solve the knob puzzle.
Figure 3: Game 1 - Smartphone application mockups

See Appendix A for all printed material provided to the players throughout this game.

4.1.2 Platform
The game is comprised of two missions, each running on a different platform.

- The first mission uses a smartphone application running on Android version 2.2 or newer. Android was selected as the mobile operating system of choice because it allows for faster prototype development by using rapid prototyping tools.

- The second mission uses a physical, wearable device based on the Arduino platform. Arduino was selected as the hardware platform because of its capacity for rapid prototyping and high extendability.

4.1.2.1 System requirements
The wearable version of the game has no requirements as the device that runs the game is provided to the users. Running the mobile application requires a smartphone equipped with a touch screen, a GPS sensor and a vibrating module. Today, all smartphones that we are aware of have these features so any smartphone using the Android OS version 2.2 or newer are compatible.

4.1.3 Gameplay
4.1.3.1 Overview
The players visit each of the three different locations in any order they choose. This has a different outcome depending on the location but all outcomes result in them getting a clue-word. The core mechanic involved in this game has to do with decoding incoming "transmissions" by turning the knobs on the screen. When a knob is in place, the smartphone will vibrate to alert the player. In the wearable version the game is identical, with the main difference being the technology used and the form factor. The device features a small screen for displaying messages and uses a physical knob instead of virtual ones.
Game difficulty changes depending on the location: the first location has a single knob to be turned, the second has two knobs while the third and final location has three knobs that must be turned to the right positions for the clue to be displayed. Upon discovering all three clues the players have to return to the starting point where the mission began and report their findings. All player teams will be timed from the moment they begin the game until this point. The fastest team will be considered the victor of this game.

4.1.3.2 Flowchart

![Flowchart](image)

**Figure 4: Game 1 - flowchart**

4.1.3.3 Controls

The mobile app version of the game uses the smartphones touchscreen for all required user input. The wearable version will use a physical knob which will have to be used an appropriate number of times depending on the location. We decided to use a single knob multiple times instead of having three different knobs on the device in order to simplify the interface and keep the wearable device as small as possible.
4.1.3.4 Mobile Application Interfaces

Below are provided wireframes of the mobile application prototype interfaces and mockups of the interface of the wearable device version of the game.

Figure 5: Game 1 - Smartphone application wireframes

Figure 6: Game 1 - Wearable game interface mock-ups
4.1.3.5 Rules
The following game rules were established:
- Players have to use the supplied devices and material such as the written letter and the map to progress in the game.
- Players can visit the game locations in any order they want to.
- Players need to discover the clues on their own.
- In order to win, a player team has to clear the game faster than the other teams.
- Players may use any means of transportation they see fit to visit the game locations.

4.1.3.6 Scoring/winning conditions
To win, the players have to discover the first three clue-words through the mobile app game. When this happens they will be provided with the wearable device which they must use to discover the last three clue-words. To finish the game, players need to send a SMS to a mobile phone number, provided in the letter from the Headquarters.

No scoring is mentioned within the game as our aim is to make it seem as real as possible, in order to enable immersion. However we recognize that scoring can be a powerful motivator for players therefore we decided to score the game depending on how long it takes player teams to finish it. The team to finish the game the fastest is considered the winner. Player scores are available in the tester list in Appendix C, at the end of this thesis.

4.1.3.7 Game Mechanics
Game mechanics are typically described as verbs describing specific methods or ways that afford agency in the game world. With this in mind we distinguished the following mechanics in the Spy Hunt game:
- Find an area of interest
- Enter an area of interest
- Turn knobs
- Report to Headquarters via SMS

4.1.4 The Game World and the Game Characters
In this section we will describe the game-world and also we will provide an overview of the characters that exist in this game.

Game World
This game takes place in the real world. Everything that has to do with the terrorists, spies and encrypted transmissions etc. is of course fictional. Key locations in the game are the six places marked on the maps provided, where the terrorist messages
are broadcasted as well as the coffee shop that serves as both a starting point and an endpoint for this game.

**Game Characters**

**PC (player character)**

The players take on the role of spies, sent by his agency to investigate what happened to a fellow agent who disappeared in the area while being undercover, posing as a member of a terrorist group. The fellow agent soon makes contact through a letter to the players and their true mission is revealed.

**Enemies**

The antagonists in this game are a group of terrorists called "18th of January". They exist only as a maleficent presence. Players never meet any enemies and the only interactions with them happen indirectly when they attempt to decode their encrypted transmissions. However, the players are not aware of this fact and are left to imagine that enemies, in the form of other players, may be around them. The enemies' plan is to carry out an attack against civilians to further their own nefarious goals.

**Allies**

The player's allies are the agency they work for and the fellow agent codenamed "Sugarman" who they were tasked to locate. They never meet any of them in person but the fellow agent leaves them a letter at the beginning of the game in order to provide them with the necessary information about how to go forward.

**4.1.5 Story**

The players play as agents for secret government agency named CIB. Activity in a terrorist group named "18th of January" prompted the agency to deploy a fellow agent and friend of the agents codenamed "Sugarman" to the city. Once there he joined the ranks of the terrorists and provided the agency with information about its activities for over a year. Sugarman has not made contact in over two weeks and it’s the players’ mission to find out what happened to the missing agent and uncover any information they can about the terrorist group. The players' first stop is a local coffee shop, where the missing agent used to pose as an employee. Once there, the players do not see Sugarman but find a package from him under the table where he used to leave dead drops for the agency in the past. In the package the players find an envelope containing a map with three locations marked, a smartphone and a letter by Sugarman. The letter goes in more detail about the fellow agent's predicament and asks the players to finish his mission and find out the details of the terrorists' plans for their next strike. The players have to visit the locations from the map and using the smartphone to decode encrypted transmissions between members of the terrorist group. This concludes the first mission of the game.
When the first three clues have been uncovered the players are approached by a stranger who gives them another package and leaves without speaking. This new package is from the CIB headquarters and contains a letter explaining the situation, a wearable device capable of decrypting more complex transmissions and a map were new locations are marked. Again the players will have to get to the different locations and this time use the wearable device to decrypt the transmissions. By the end the players will have gathered six clues containing enough information to pinpoint where, when and how the terrorist attack will take place. Finally, the players will have to send an SMS containing the six clues to a safe number provided by their agency. This signifies the end of the second part and of the game as well.

4.1.5.1 Narrative devices
To reveal the story in this game, we made use of a few different narrative devices. We used a letter written by fellow spy Sugarman and one written by the players’ superiors. We also used two maps with different locations marked in them, in order to inform the players of the places they need to visit to get the needed clues.

4.1.5.2 Development platform and tools
To develop the smartphone application version of this game we used a tool for Android application development named App Inventor. App inventor [38] is an online tool for developing android applications, which was developed by Google and is maintained by MIT. We used App inventor to develop our digital prototype, because it allows for creating and testing digital prototypes in a rapid fashion. Development in App inventor is also simplified compared to traditional application development, allowing for more focus on the nature of the application being developed and the interactions it contains and less on the more technical issues.

To develop the wearable version of the game we used the Arduino platform [42]. Arduino is an open-source electronics prototyping platform that is both flexible and easy to use. Today, there also exist other similar platforms for developing hardware prototypes however, Arduino is arguably the largest, boasting a big community of users who contribute with valuable software libraries. The Arduino micro-controllers are programmed through the Arduino IDE, using an implementation of Wiring, which is based on the Processing multimedia programming environment. We have chosen this platform to develop the wearable version of the game because of the reasons we mentioned earlier as well as the fact that we had access to compatible electronics and some experience in using them.

The main electronics components used to create the wearable device are an Arduino Nano single-board microcontroller, a GPS module, an OLED screen and a potentiometer to act as the knob. Below we see screenshots from the final version of the Spy Hunt smartphone game prototype as well as a picture from the wearable device game prototype.
Figure 7: Game 1 - Final smartphone application prototype

Figure 8: Game 1 - Final wearable prototype
4.2 Game 2: Simon Says

The second game we designed bears a few similarities to the previous game, especially so in the technical approach. However, it also has important differences in other areas like gameplay mechanics and plot, therefore we will focus more on these differences as we describe the game.

4.2.1 Gameplay synopsis

This is a pervasive game based on the familiar game also named Simon Says. Simon Says is essentially a memory game where the players have to memorize and repeat a pattern of pictures, colors or sounds. The sequences to be remembered become incrementally longer as the game progresses making them more difficult to recall. In this version of the game we have chosen to use alternating sequences of colors in each round instead of simply adding more colors to the same sequence. We made this choice in order to make the game more challenging and keep the players’ attention.

In this game the players take on the role of police detectives, who are on the trail of what they think is a terrorist group. They received a mysterious package at their office containing a smartphone, a wearable device and a note asking them to visit a local electronics megastore that also sells books. The note directs the detectives to a specific book about a real-world terrorist group called “17N”. Upon opening the book they find a letter directed to them from a mysterious group. The letter accuses the megastore of closing down small local businesses while taking advantage of their staff and threatens to exact vengeance on the customers that support it. The players are given a chance to prevent something horrible from happening by using the tools they have been given and proving they are worthy opponents.

Once again the letter’s aim is to explain the situation to the players, introduce them further to the story and help facilitate immersion. Unlike the previous game, this game is not location-based and is played entirely in the bookstore section of a local megastore. Upon starting the mobile application the players are shown a series of colors which they have to repeat using the buttons on the screen. The color sequences start at just one color but go higher and higher as the players progress through the rounds. Upon completing a level, the players are rewarded with a set of numbers and the ID of a book in the store. The players have to locate that book and use the numbers to find the clue in the pages of the book. The numbers are a cipher pointing to the specific word in the book that is the clue-word. Upon gaining their third clue the players will discover that the wearable device no longer works and they will have to switch to the mobile application and use it in a similar fashion to uncover the remaining clues.

Below we see the first mockups of the smartphone application's interface. The first screen is what the players see when they are not engaging in a Simon Says game. The second screen appears once they start such a game and the third once they successfully complete the game.
See Appendix B for all printed material provided to the players throughout this game.

4.2.2 Platform
This game is also comprised of two parts, each running on a different platform.
- The first part is a smartphone application running on Android version 2.2 or newer.
- The second part is played using a physical, wearable device based on the Arduino platform.

4.2.3 Gameplay
4.2.3.1 Overview
The players will use the wearable device first, to uncover the first three clues. To do this they have to successfully beat the memory game, by watching the pattern as it is displayed and repeating it accurately, clicking the appropriate buttons. If they make a mistake the sequence will reset and they will have to start over. When they succeed they will have to locate the book mentioned and use the cipher they were given to find the required word. The final three clues will have to be found by using the smartphone version of the game which is identical aside from the fact that uses the touchscreen for input and output.
4.2.3.2 Flowchart

[Flowchart image]

4.2.3.3 Controls

The mobile app version of the game used the smartphone's touchscreen for all required user input. The wearable version used four physical buttons connected to a color screen which had to be pressed in the appropriate order, as well as a submit sequence button.

4.2.3.4 Rules

The following game rules were established:

- The players have to use the supplied devices and material such as the written letter and the books to progress in the game.
- The players need to discover the clues on their own.
- The players may ask the store staff for directions to any of the books.
- In order to win, the players need to make sense of the clues they gathered and report back to the starting point.
4.2.3.4 Scoring/winning conditions
To win the players have to find the six clues by playing the game on both the smartphone and on the wearable device. Once all clues have been uncovered the players need to decipher the motives and plans of the antagonists and report back to the starting point.

No scoring is mentioned within the game but we have decided to score the game depending on how long it takes a player to finish it. The player team to finish the game first is considered the winner. Player scores are available in the tester list in Appendix C, at the end of this thesis.

4.2.3.5 Game Mechanics
We distinguished the following game mechanics in the *Simon Says* game:
- Repeat color pattern
- Find book
- Use cipher to find word in book

4.2.4 The Game World and the Game Characters
In this section we will describe the game-world and also provide an overview of the characters that exist in this game.

**Game World**
This game takes place in the real world. Everything that has to do with the threat posed in the game is of course fictional but the antagonists motives are based on facts so as to bring the game closer to reality and help facilitate immersion in the game.

**Game Characters**

*PC (player character)*
The players play as a duo of detectives from the local police department. They went to the megastore looking for clues that might lead them to identify the perpetrators of a series of crimes. They soon find that everyone inside the building is in danger and the only way they can save the lives of the store’s customers and staff is to beat the antagonists in their own game.

*Enemies*
The antagonists are a group of unknown individuals whose motives remain mysterious. The players never meet any of them and interact with them indirectly through the game. The enemies’ plan is to carry out an attack against the customers and staff of the megastore in order to exact revenge for the effects of the store on the local community. They give the players a chance to stop the coming catastrophe, if they can prove themselves smart enough to uncover their plans and identity.
**Allies**

The players have no allies in this game, but may use the store’s staff to help them with their mission. The staff is unaware of what is going on in the game.

### 4.2.5 Story

The players play the part of two police detectives working at the local police station. They have been investigating a series of unsolved crimes for some time now and have made the hypothesis that there is a connection between them. This has drawn the attention of the antagonist group which proceeded to send the duo a package containing a message inviting them to the megastore as well as a smartphone and a wearable device. The message also named the title of a book on a real-world terrorist group called November 17th or “17N”. Once the detectives find this book on the store’s selves, they discover a letter between its pages. The letter is addressed to the detectives and is by a group that identifies itself as a “Group of friends”. The letter accuses the megastore of strangling the small local businesses to the point of shutting down, while taking advantage of their own employees, paying them unfair wages. The authors threaten to exact vengeance on everyone involved in this, including the customers that support the evil megastore.

However, they appreciate intelligence and so challenge the players to uncover the group’s identity as well as what their plans are.

The players have to start by using the wearable device they have been given. The device is a memory game, flashing color sequences that the players have to remember and repeat. On success they proceed to more difficult sequences until they complete the challenge and are rewarded with a cryptic message comprised of a book title and some numbers. These numbers are in reality a cipher that when used with book identified yield a clue. This process is repeated with the player trying to locate the needed books and discover the clues to this mystery as fast as possible. After the players receive the third clue from the wearable device, they find that it does not work anymore and will have to use the *SimonSays* application on the smartphone they were given to proceed.

When all six clues have been discovered, the players will have to send an SMS containing the clues to a number provided in the letter. The six clues will contain the identity of the group as well as the nature of the planned attack.

### 4.2.5.1 Narrative devices

The main narrative device used in this game is the letter from the antagonists. However, as the players collect the clues they will begin to understand more about the enemy's motivation and plans, so the clues themselves are part of the narrative.

### 4.2.6 Development platform and tools

This game was developed in the same way as the first game presented in this thesis: *Spy Hunt*. The tools we used were MIT App Inventor and the Arduino platform.
hardware prototyping platform. The main electronics components used to create the wearable device used in this game are an Arduino UNO single-board microcontroller and a 16x2 color screen shield.

Below we see screenshots from the final version of the Spy Hunt smartphone game prototype as well as a picture from the wearable device game prototype.

Figure 11: Game 2 - Final smartphone application prototype

Figure 12: Game 2 - Final wearable prototype
5. Data Analysis and Evaluation

This chapter contains the analysis and evaluation of the data we collected via the RGT. The data in its raw form is seven separate filled in Repertory Grids, each filled by a different group of two participants. In total, these contain 59 elicited constructs as well as two fixed constructs which were filled in by all of the seven tester groups, yielding a total 73 constructs. We used an online software tool named WebGrid5 for our analysis, using its functions to create various visualizations of our data which we then interpreted.

In the following sections we will use a process for merging multiple constructs which are semantically similar into single constructs, which is based on the work of Fallman. An overview of the steps to this process can be seen in the list that follows:

Step 1 – Identify a group of constructs which are semantically similar.
Step 2 – Create a table with rows corresponding to each of the elements.
Step 3 – Enter the values an element scored in each of the constructs in that row.
Step 4 – Re-arrange the values in each row from low to high to help identify the medians. These best represent the testers’ opinions as the effect few extreme values on the overall score of an element is mitigated.
Step 5 – Calculate the median values using the process described below.
Step 6 – Create a new construct, which captures the essence of the original constructs. Its poles are named after the original constructs’ poles and its links (values) are the median values calculated in step 5.
Step 7 – Substitute the original constructs in the repertory grid with the new, merged construct.

To identify the median values of each element in the table, we use the following process which is also based on the work of Fallman:

If the number of constructs in the group is odd, then the middle column contains the median values of all elements. In these cases we highlight the middle column. If the number of constructs is even, then the median values need to be calculated by getting the average of the two middle columns rounded down. In these cases we add a separate, highlighted column at the end of the table, containing the median values.

5.1 Fixed Construct Analysis

The first step in our analysis was to separate the fixed constructs which were chosen to focus on immersion, from the constructs elicited from the testers, and create a table from them. These fixed constructs help us answer our first research question which is “How does the type of mobile platform itself affect the perceived immersion?” As there are only two constructs that are repeated seven times each in this table, we are not interested in identifying similarities between the constructs themselves, but want to identify any similarities between the elements due to the constructs. Specifically, by
finding which element is closer to the element we named “Ideal” we can find which
game the testers regarded as closer to their ideal game with regards to immersion.

As we mentioned in chapter 3, the two fixed constructs we used were Engaging – Boring and Absorbing - Uninteresting and were selected because they are semantically very similar according to the online thesaurus tool we used [36]. This was done to capture the same meaning, which is on the topic of immersion. We refrained from using the word immersion itself as the testers were aware of its use in our research and we believe may have skewed their answers. We proceeded to merge these multiple semantically identical constructs into a single merged construct, which we named Engaging – Uninteresting.

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Entering the ratings of each element in a table we can easily discern the median values, which are the scores of each element in the new, merged construct which we named Engaging - Uninteresting.

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<td>4</td>
</tr>
<tr>
<td>G2M</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Ideal</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 1 - Element immersion values and median
We see that both smartphone-based pervasive games have median values of 3, while both wearable pervasive games share a median value of 2, with the Ideal pervasive game having a value of 1.

We can therefore conclude that the wearable mobile platform affects perceived immersion in pervasive games positively compared to the smartphone mobile platform, answering our first research question. This is also verified by the mapping of the merged construct *Engaging - Uninteresting* seen below in Figure 14, were the wearable games are located closer to the ideal pervasive game and are ranked as more *Engaging* than their smartphone-based counterparts, which are considered rather *Uninteresting*.

![Figure 14: Plot of fixed constructs](image)

5.2 Elicited Construct Analysis

The PRINCOM map generated through WebGrid5 using all of the 59 constructs is large and chaotic making deriving meaning from it more difficult (figure 16). Our aim in analyzing the elicited constructs is to answer our second research question, identifying the specific benefits and challenges for smartphones and wearable computing devices in the context of pervasive games. As the constructs were elicited from each tester group individually, there are multiple constructs that have similar meanings or in some cases are even identical, as different groups used the same words to describe aspects of their experience with the games.
We therefore decided to follow the approach used by Fallman[37], and group these constructs. As in this thesis we are not interested in detecting similarities between constructs but their relationship to each of the elements, we decided to group the constructs that are semantically similar, creating groups of similar meaning by detecting emerging themes that came up during the interviews.

<table>
<thead>
<tr>
<th>Display sum of grids</th>
<th>“Thesis”</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>No memorizing</td>
<td>1 1 5 5 3</td>
</tr>
<tr>
<td>Easier to proceed</td>
<td>2 1 5 5 4</td>
</tr>
<tr>
<td>Requires both passive and active actions</td>
<td>3 6 5 6 1</td>
</tr>
<tr>
<td>Interesting</td>
<td>3 6 5 6 1</td>
</tr>
<tr>
<td>More steps</td>
<td>5 5 2 2 1</td>
</tr>
<tr>
<td>Tactile</td>
<td>2 5 1 5 1</td>
</tr>
<tr>
<td>In thematic areas</td>
<td>6 5 3 3 1</td>
</tr>
<tr>
<td>Existing</td>
<td>1 3 3 5 1</td>
</tr>
<tr>
<td>In large area</td>
<td>1 1 5 5 3</td>
</tr>
<tr>
<td>Uses sound</td>
<td>6 5 6 5 1</td>
</tr>
<tr>
<td>Draw attention</td>
<td>1 5 5 5 2</td>
</tr>
<tr>
<td>Tactile</td>
<td>2 5 1 5 2</td>
</tr>
<tr>
<td>Multiple locations</td>
<td>3 3 5 5 1</td>
</tr>
<tr>
<td>Virtual output</td>
<td>4 5 3 4 1</td>
</tr>
<tr>
<td>Difficult</td>
<td>5 4 3 4 2</td>
</tr>
<tr>
<td>Small device</td>
<td>5 5 3 3 2</td>
</tr>
<tr>
<td>Complex</td>
<td>5 5 2 2 1</td>
</tr>
<tr>
<td>Fun</td>
<td>3 3 2 5 1</td>
</tr>
<tr>
<td>Attractive</td>
<td>2 4 1 5 1</td>
</tr>
<tr>
<td>Both screen and tactic</td>
<td>4 3 3 5 1</td>
</tr>
<tr>
<td>Modern-easy to use</td>
<td>5 1 4 1 1</td>
</tr>
<tr>
<td>Modern-easy to use</td>
<td>5 1 4 1 1</td>
</tr>
<tr>
<td>Sophisticated</td>
<td>3 4 2 1 1</td>
</tr>
<tr>
<td>Uses actors/other players</td>
<td>4 4 2 5 1</td>
</tr>
<tr>
<td>In many places</td>
<td>2 2 3 3 1</td>
</tr>
<tr>
<td>Uses environment</td>
<td>2 2 3 3 1</td>
</tr>
<tr>
<td>Requires investigation</td>
<td>4 4 2 2 1</td>
</tr>
<tr>
<td>New experience</td>
<td>3 4 2 4 1</td>
</tr>
<tr>
<td>Challenges only in game</td>
<td>3 3 3 2 1</td>
</tr>
<tr>
<td>Easy to use</td>
<td>3 2 4 2 1</td>
</tr>
<tr>
<td>Stands out</td>
<td>3 5 1 5 3</td>
</tr>
<tr>
<td>Open in bin</td>
<td>5 6 4 4 1</td>
</tr>
<tr>
<td>More due sources</td>
<td>5 5 3 3 1</td>
</tr>
<tr>
<td>Accurate</td>
<td>5 3 1 1 1</td>
</tr>
<tr>
<td>Known battery left</td>
<td>5 1 5 1 1</td>
</tr>
<tr>
<td>Played indoors</td>
<td>5 5 3 3 3</td>
</tr>
<tr>
<td>Study</td>
<td>4 1 3 1 1</td>
</tr>
<tr>
<td>Uses both locations and items</td>
<td>5 5 2 2 1</td>
</tr>
<tr>
<td>Is worn</td>
<td>1 5 1 5 1</td>
</tr>
<tr>
<td>Inconspicuous</td>
<td>5 1 5 1 5</td>
</tr>
<tr>
<td>Active</td>
<td>5 2 4 1 1</td>
</tr>
<tr>
<td>Requires attention</td>
<td>4 5 1 2 3</td>
</tr>
<tr>
<td>Simple</td>
<td>4 3 4 4 4</td>
</tr>
<tr>
<td>Gradual progress</td>
<td>5 5 4 4 1</td>
</tr>
<tr>
<td>Navigation through stress</td>
<td>3 3 2 2 3</td>
</tr>
<tr>
<td>Handheld</td>
<td>5 1 5 1 5</td>
</tr>
<tr>
<td>Player is active</td>
<td>6 5 3 3 1</td>
</tr>
<tr>
<td>Does not draw attention</td>
<td>3 1 5 4 1</td>
</tr>
<tr>
<td>Thrilling</td>
<td>4 2 3 4 1</td>
</tr>
<tr>
<td>In one building</td>
<td>3 3 1 1 3</td>
</tr>
<tr>
<td>Thematic</td>
<td>2 3 4 5 1</td>
</tr>
<tr>
<td>Mobile</td>
<td>5 1 4 4 1</td>
</tr>
<tr>
<td>Requires focus</td>
<td>4 4 1 2 4</td>
</tr>
<tr>
<td>Immersive difficulty</td>
<td>1 2 5 4 1</td>
</tr>
<tr>
<td>Easy to use</td>
<td>3 1 5 1 1</td>
</tr>
<tr>
<td>Requires walking</td>
<td>1 1 5 3 3</td>
</tr>
<tr>
<td>Interactive</td>
<td>1 2 4 4 1</td>
</tr>
<tr>
<td>Strange</td>
<td>2 5 1 5 3</td>
</tr>
</tbody>
</table>

Figure 15: Original elicited constructs, numbered
Above we see the full list of the original elicited constructs we gathered. It was created by compiling the seven individual grids we created from each of our tester groups, into a single grid. Figure 16 below is the PRINCOM map of the constructs presented in Figure 15.

Figure 16: PRINCOM map of original elicited constructs
5.2.1 Grouping and merging elicited constructs

In this section we present the groupings we made from the elicited constructs, analyzing briefly the implications of each new construct.

**Group A – Form factor**

![Figure 17: Construct group A](image)

Constructs 46 and 39 are very similar. We merged them into a construct titled: *M1 Worn – Handheld*. As they are ranked identically the new construct has the same values as they do.

**Group B – Location**

![Figure 18: Construct group B](image)

Constructs 9, 13, 25, 36, 50, 53, 57 are on the topic of location. Some of the testers enjoyed playing outdoors while others preferred playing inside. We merged these constructs into a new construct titled: *M2 Requires walking – Indoors*. We again found the median values of the original constructs to assign values to our new construct.
Table 2- Median values of group B

The median values point out that the ideal game is played in more locations than our indoors pervasive games but less than our outdoors game. It was apparent in our interviews that this factor is highly subjective. We suspect that a game that would let the players choose where to play might be the optimal solution.

Group C– Ease of use

Constructs 21, 22, 29, 30, 56, 34, 35, 55 are on the topic of the devices’ ease-of-use. We merged them into a construct titled: M3 Easy to use –Practically difficult.

Table 3- Median values of group C
As is pointed at by the median values above, the wearable prototypes were harder to use than their mobile application counterparts. Among the issues were bulkiness, uncertainty with regards to user input and battery life. The testers did not appreciate game difficulty due to hard to use devices. We are certain that all of these usability issues could be overcome in more refined iterations of our wearable devices.

**Group D – Attention Drawing**

Constructs 11, 31, 40, 48 are all on the topic of the players drawing attention while playing the pervasive games. We merged them into a construct titled: *M4 Draws attention–Inconspicuous*.

![Figure 20: Construct group D](image)

<table>
<thead>
<tr>
<th>Game</th>
<th>W</th>
<th>1</th>
<th>3</th>
<th>3</th>
<th>MEDIAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1 W</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>G1 M</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>G2 W</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>G2 M</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Ideal</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>2</td>
</tr>
</tbody>
</table>

*Table 4 - Median values of group D*

All testers agreed that the wearable prototypes stood out a lot more than the smartphones did. It is nowadays very common to see people playing games on their smartphones but less so playing games on wrist-mounted devices. Whether the players enjoyed the attention they drew from others while they played the pervasive games is again a subjective matter. Several of our testers stated that they enjoyed drawing looks from puzzled strangers, while others hesitated to wear the wearables because they were concerned about drawing attention to themselves. As wearable devices become more common we expect their use will draw less attention in the future.
**Group E – Game difficulty**

Constructs 2, 15, 17 and 43 are concerned with the difficulty of the games. We merged them into a construct titled: *M5 Simple – Complex.*

![Display Group E “Thesis”](image)

**Figure 21: Construct group E**

<table>
<thead>
<tr>
<th>Game</th>
<th>G1 W</th>
<th>G1 M</th>
<th>G2 W</th>
<th>G2 M</th>
<th>Ideal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>MEDIAN</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

**Table 5 - Median values of group E**

As we can see in the table above, the second game’s difficulty is just right according to the testers while the first game was rather easy to complete. It is not surprising that there are no significant differences between the smartphone and wearable versions of the games as the game implemented is basically the same.

**Group F – Fun**

Constructs 4, 8, 18, 19, and 49 have to do with how enjoyable playing each game was. Our testers used quite a few different words to describe whether they liked each of the games. We merged these into a construct titled: *M6 Fun – Not exciting.*
The median values in the table above show that players had the most fun playing the wearable version of the second game followed closely by the wearable version of the first game. The smartphone versions of the pervasive games were both ranked lower, verifying our expectations from our testers’ reactions during the interviews.

**Group G– Tactile Interface**

Constructs 6, 12, 20 and 51 have to do with the sense of touch in the game prototypes, meaning whether the interface to the game was tactile and to what degree. We merged these into a construct named: **M7 Tactile – Touchscreen.**
The table above shows that the tactile interface was favored by the majority of our testers, while the touchscreen interface seemed ordinary and unexciting. It is worth pointing out that some of our testers stated that they would have liked to use a combination of both tactile and touchscreen interfaces in the games.

**Group H—Active-passive**

Constructs 3, 41, 42, 47, 54 and 58 mention how active players had to be while playing each of the games. We merged them into a construct named: *M8 Player is active–Relaxed.*

The median values in the table above confirm our expectations from the interviews that players wanted to be more active in the games, being afforded more...
actions and being led to clues less. While some of the testers were more keen to be active than others we feel it is a valid point that should be heeded in future pervasive games we make, when there are fewer time constrains for both testing and prototype development.

5.2.2 PRINCOM Mapping of processed constructs

The new constructs we created in the previous section encapsulate the meaning contained in the original constructs by the testers. This process reduced a total of 39 constructs into 8 new constructs:

- M1 Worn – Handheld
- M2 Requires walking – Indoors
- M3 Easy to use – Practically Difficult
- M4 Draws attention – Inconspicuous
- M5 Simple – Complex
- M6 Fun – Not exciting
- M7 Tactile – Touchscreen
- M8 Player is active – Relaxed

Aside from the eight new constructs we have twenty more which did not fit in any semantic category we could identify. We used these twenty eight constructs to create a refined version of our original elicited construct repertory grid.
We then created a PRINCOM map using this processed repertory grid. This visualization shows us the relative positions of our elements to each other as well as from the construct poles. The construct poles closest to each element are the ones that characterize it the most, according to our testers, helping us answer the second research question of this thesis which is “what specific benefits and challenges may be identified for smartphones and wearable computing devices in the context of pervasive games”. 

Figure 25: Processed repertory grid
Regarding the relative positions of the construct poles to the elements we can tell which characteristics seem to be most tied to the wearable and which to the smartphone versions of our games. The smartphone versions of our pervasive games were considered familiar, inconspicuous, casual, thematically random and sturdy but not very exciting. They are easy to use and small compared to the wearable devices, but their touchscreen characteristic is situated far from the ideal game.

The wearable versions were considered more thematic, a new experience and fun. They were also strange compared to the smartphones and drew the attention of others, while they were considered fragile compared to smartphones. Their tactile
characteristic is placed closer to the ideal game suggesting that tactile interfaces are part of an ideal pervasive game experience.

Looking at the construct poles closer to the ideal game, we see our testers’ suggestions of features an ideal pervasive game should have. These include the use of sounds, multiplayer modes, open time limit of when the game can be played and gradual progression through the game rather than knowing what will happen in the game from the start. A pervasive game should also be played in thematic areas so as to make easier the switch from the game world to the real world. Players also wanted more clue sources and the use of the environment and items in it as such. We initially intended to incorporate clue sources like these in the games but were unable to, due to time constrains as well as the need to have more control over the urban environment to do so. The ideal pervasive game should also be larger, more sophisticated and challenging, requiring the players to dig deeper in order to advance.

Regarding the relative positions of the elements to each other, we immediately see that the ideal pervasive game I placed far from all four of our pervasive game prototypes. To see the exact distance between them we used another function of WebGrid5 which displays the degree to which elements match each other. As we see below in Figure 26, the game prototype closest to the ideal is the wearable version of game 2, Simon Says, which matches the ideal game 50.9%. The rest of the pervasive game prototypes fall behind with the smartphone version of Simon Says being at 45.5%, the wearable version of Spy Hunt being at 38.4% and its smartphone version matching the ideal game at 34.8%. The ideal is still far from our game prototypes but this was expected for our simple game prototypes. The most interesting part in our opinion is that in both games the wearable versions scored higher than the smartphone versions of the same game, despite the relative roughness of the wearable prototypes. We believe that more refined versions of the wearables, which would improve issues such as their sturdiness, their feedback accuracy and their looks, could very well allow them to score higher coming closer to the ideal pervasive game.
6. Conclusion

In this chapter we present a summary of the results we obtained from analyzing the collected data in the previous chapter, we discuss the study's limitations and suggest possible future work.

6.1 Summary

In this thesis we identified and proceeded to answer two research questions:

1) **How does the type of mobile platform itself affect the perceived immersion?**
   
   Our analysis of the data collected from the fixed constructs, as it was presented in section 5.1, suggested that the wearable platform affects user-perceived immersion positively compared to the smartphone platform.

2) **What specific benefits and challenges may be identified for smartphones and wearable computing devices in the context of pervasive games?**

   An overview of the results gleaned from the analysis of the elicited constructs, as it was presented in section 5.2, can be viewed in table 9 below where the answer to our second research question is summarized.

![Matches Between Elements](image.png)

*Figure 27: Matches between elements*
<table>
<thead>
<tr>
<th>Platform</th>
<th>Smartphones</th>
<th>Wearables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Features</td>
<td>identified</td>
<td></td>
</tr>
<tr>
<td></td>
<td>familiar</td>
<td>a new experience</td>
</tr>
<tr>
<td></td>
<td>inconspicuous</td>
<td>attention drawing</td>
</tr>
<tr>
<td></td>
<td>casual</td>
<td>worn</td>
</tr>
<tr>
<td></td>
<td>thematically random</td>
<td>thematic</td>
</tr>
<tr>
<td></td>
<td>sturdy</td>
<td>fragile</td>
</tr>
<tr>
<td></td>
<td>not very exciting</td>
<td>fun</td>
</tr>
<tr>
<td></td>
<td>easy to use</td>
<td>strange</td>
</tr>
<tr>
<td></td>
<td>small</td>
<td>clunky</td>
</tr>
<tr>
<td></td>
<td>touchscreen</td>
<td>tactile</td>
</tr>
</tbody>
</table>

*Table 9 - Analysis Results*

Finally, in the following table we see user-suggested features for pervasive games that were considered desirable by our testers.

<table>
<thead>
<tr>
<th>Wanted Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>use of sounds</td>
</tr>
<tr>
<td>multiplayer modes</td>
</tr>
<tr>
<td>open time limit</td>
</tr>
<tr>
<td>gradual progression</td>
</tr>
<tr>
<td>played in thematic areas</td>
</tr>
<tr>
<td>more clue sources</td>
</tr>
<tr>
<td>use of the environment and items in it</td>
</tr>
<tr>
<td>larger</td>
</tr>
<tr>
<td>sophisticated</td>
</tr>
<tr>
<td>challenging</td>
</tr>
<tr>
<td>players dig deeper in order to advance</td>
</tr>
</tbody>
</table>

*Table 10- Wanted features in pervasive games*

6.2 Discussion

In this thesis we designed and created two pervasive games each with two prototypes, in the smartphone and wearable platforms. During the game design process we heeded a number of suggestions found in our literature review: We used technology not as a decorative element but to provide play opportunities as suggested by Jonsson et al. [25], while every piece of technology was written into the scenario of the games as suggested by Waern et al. [23]. We refrained from having our players engage in strange
or anti-social behavior or of challenging the social norms in any way heeding the advice of Linehan et al. [22]. We heeded Jegers’s [28] advice and attempted to simplify the process of the mental switch from the real-world to the game-world, by having the game take place in a version of the real world. We also divided the game in steps to support the formulation of goals by the players, while scaling the difficulty as the games progressed. Our players approached our pervasive games as something new and not as normal computer or smartphone based games as Bertelsmeyer et al. [21] suggested might happen, and while physical skills may have played a part in the Spy Hunt game, where players had to walk around the city to key areas, this was mitigated by the other skill requirements as is proved by the fact that the winners of the game were not the ones who were physically strongest. Wearing and using the wearable devices made some of our players uncomfortable as happened in the game created by Ballagas et al. [14] but thankfully in our case no accidents were caused due to passers-by getting distracted by our players.

We did not heed the suggestions of Korhonen et al.[15] on making our games adjustable to our testers’ schedules due to limitations. Our testers verified this need by making Open time limit a construct pole closely related to their ideal pervasive game, validating this point.

Finally, we detected elements of the ectodiegetic immersion as reported by Oliveira et al. [18] in our game in three instances. In the Simon Says game, one of the clue-words we chose from one of the books was on a page containing a reference to website. Some of our players assumed that this was intentional and proceeded to visit the website being more immersed in the game world. Also, in the Spy Hunt game one of the random locations we chose in the city was near a travel agency, and one near a private investigator’s office. Some of our players believed there was reasoning behind this and were briefly looking for connections to these areas experiencing ectodiegetic immersion.

6.3 Limitations

There are some limitations that we can identify in this study. First, the sample size we used while sufficient according to the literature is not as large as we would have liked. The testers while having diverse backgrounds and being of both genders are also not diverse enough and we believe this has to do with the use of Snowballing to get them, as we mentioned in chapter 3. Friends of testers are likely to have shared experiences with them, possibly making their input less valuable. Also, the age group to which our testers belong is rather small with their ages being from 22 to 36.

While the wearable and smartphone prototypes had obvious weaknesses such as bulkiness, fragility and very basic interfaces, we do not think this affects the validity of our results, as these prototypes are for the most part compared to each other and when compared to the ideal pervasive game, what we get is suggestions on how to improve on them. Finally, we are aware that there also exist many wearable devices that are not tactile, using touchscreen interfaces that make them resemble worn
smartphones. Investigating were these fit in the context of immersion in pervasive games requires further testing and is one of the topics future work should address.

6.4 Future Work

In this thesis we have investigated pervasive games that either use smartphones or wearable devices as the means through which they are played. It is however possible to have such games that use both wearables and smartphones simultaneously to engage the players. This approach was also suggested by some of our testers as well. We therefore propose that the next step could be researching games that use this combination and investigate if and how they differ from pervasive games played on any single platform.

We also believe that it would be interesting to explore different game mechanics and how they affect immersion. Finally, another point worth investigating is if the wearable device's size also affects immersion and player enjoyment.
References

Appendix A - Spy Hunt printed material

Introductive letter

You are spies working for the CIB secret service. You have been sent to this city to find out what happened to a friend and fellow agent codenamed "Sugarman", with whom you have worked together in the past. He was working undercover in a terrorist group hiding in the area. He has not reported back to the Headquarters in over three weeks.

Your first stop in this mission is the cafeteria where "Sugarman" posed as a waiter. You sat down on one of the tables and looked underneath, at the old pick-up spot where "Sugarman" used to leave information for you when you worked together...

At the end of the mission send your findings by SMS to 6976857032, CIB's safe line. Then return to the starting point.

Sugarman’s letter

Agents,

Something big is going to happen but I don't know what. A MESSAGE is being communicated. We have to decrypt it before it's too late! I took a risk and stole one of their phones. They use them as decryption devices. Use it with the map and send your findings to the headquarters.

I cannot!

I think they are on to me!

The clock is ticking...

-Sugarman
Letter from the Headquarters

Thanks to you we now have crucial information about the terrorists' plans. We need you to finish the mission! Right now they are more cautious than ever: our intelligence suggests that they have added another level of encryption. Use the device our lab made and the map, uncover their plans and report back to us ASAP! Good Luck Agent!

-HQ
Appendix B- Simon Says printed material

Introductive letter

You are police detectives investigating a series of seemingly random attacks. You saw patterns where no one else did and made connections between seemingly irrelevant crimes. You drew their attention so they sent you the following message “Public Piraeus, 2nd floor. Find 17 N - come alone”. And here you are in the store...now where is that book?

Letter from the terrorist group

Hello officers,

Cicero once said that “A room without books is like a body without a soul.” Look around. Does this room have a soul? We know it does not. This room is part of an evil corporation. It is founded on corruption, it exploits its workers making them slave for cents while destroying the small businesses leading honest people to poverty and suicide. We will make them pay as well as everyone supporting this crime!

But... to make this fun we will give you a chance to stop it. Use our toys, uncover who we are and what is going to happen and you just might become a “hero”.

Oh, and we are watching you so no cheating calling your buddies from the office :)

Our favorite quote about books is by Frank Zappa “So many books so little time”

-till we meet

again

Your friends
## Appendix C - List of participant testers

<table>
<thead>
<tr>
<th>Group</th>
<th>Player ID</th>
<th>Age</th>
<th>Sex</th>
<th>Gamer</th>
<th>Player ID</th>
<th>Age</th>
<th>Sex</th>
<th>Gamer</th>
<th>Spy Hunt finish time</th>
<th>Simon Says finish time</th>
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