TALLINN UNIVERSITY
School of Digital Technologies

AUGMENTED REALITY GAMES FOR INCREASING PHYSICAL ACTIVITY

Master's Thesis
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Abstract

Lack of physical activity is a key factor to many chronic diseases and health problems. Computer and video games contribute to sedentary lifestyle, but a new generation of active games, or exergames, is meant to combine the fun and entertainment of gaming with the effectiveness of physical exercising. The age of smartphones and advancement in augmented reality technology enabled the mobility of such games, encouraging players to go outdoors, increasing the health benefits.

This master's thesis examines the present situation in console and mobile exergaming through literature review and describes the case study of a mobile game "SpecTrek". A multimethod approach, including pedometer, map tracking, observation, interviews and Game Experience Questionnaire, was used to measure the level of physical activity in participants during a 45-minute gaming session and evaluate their overall experience with the game.

The empirical evidence from the case study combined with the theoretical knowledge revealed that mobile augmented reality games are able to increase physical activity to some extent, but they cannot fully substitute actual exercising. Although the majority of participants showed interest in augmented reality technology and enjoyed the gaming process, claiming that it could encourage them to move more. At the least, exergames have a great potential in promoting active lifestyle and making players more aware of their health. For that reason, this thesis also covers advantages and disadvantages of such games, as well as important requirements for development of engaging and motivating mobile exergames.

Keywords: exergaming, location-based games, augmented reality, sedentary lifestyle

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Introduction

It is no doubt that technical progress gave us many advanced technologies and devices, which made our lives significantly easier, but at the same time, lazier. New technologies are helping people to reduce the amount of physical labour and energy spent on accomplishing many tasks in their everyday life. However, the nature of human body anticipates frequent movements and intensive physical work. The lack of those prevents normal development and function of different body systems (e.g. skeletal, muscular, cardio-vascular and metabolic). Sedentary lifestyle has become quite common nowadays, especially in the developed countries. Playing sedentary video and computer games can be considered one of the behaviours contributing to this problem as well as several other health issues.

People addicted to video/computer games spend most of their time at home, playing on console or computer (Mentzoni et al., 2011; Weinstein, 2010; Griffiths & Meredith, 2009; Wenzel et al., 2009). Weinstein calls computer game addiction "an excessive or compulsive use of computer and video games that may interfere with daily life". According to Griffiths and Meredith, Internet and online MMORPG (Massive Multiplayer Online Role-Playing Game) games in particular may be facilitating this circumstance by adding online game addiction to the list. Such problematic behavior has a strong impact on both mental and physical health of addicted gamers. Wenzel marks out sleeping problems, depression, suicide ideations, anxiety, obsessions/compulsions and alcohol/substance abuse among the negative consequences of excessive gaming in adult population. People play computer games because they are fun, exciting and challenging (Griffiths & Hunt, 1998), additionally, in the further studies (Griffiths, Davies & Chappel, 2004) they point out that individuals who face various life pressures may also play for escapist reasons. Yee (2004) distinguished three basic components as motivators for playing: achievement, social and immersion.

While all these game qualities are indeed motivating, there are also other, more evident reasons people play games – entertainment and killing time. Unfortunately, often along with killing time, they are also killing their health, but what if playing games could actually help maintaining healthy lifestyle, by combining them with exercising? Several researches have studied the effectiveness of so-called exergames (Graves et al., 2010; Perron, Graham & Hall, 2012; MacArthur et al., 2014) and found out that they can provide light to moderate PA and impact health and well-being of the players. However, at the same time, other researchers claim that despite the good results shown by exergames, players are confined to

a fixed room (Buddharaju & Pamidi, 2013; Barnett et al., 2013) and are limited by a region that a motion-sensitive camera can caption (Mortazavi et al., 2014). These factors may hinder and/or decrease the effects of exergaming.

During the last 5-8 years, the use of mobile devices has increased dramatically, and by 2014 mobile users have finally overtaken the desktop users (Bosomworth, 2015). This mobile "revolution" has literally liberated us from wires and brought freedom of movement. Now being attached to the computer all day long is no longer necessary. Many activities, like checking and writing e-mails, reading news or communicating with friends on social networks, can be done on the go, using mobile devices.

This also applies to playing games. The mobility advantage of smartphones and tablets combined with exergaming can be used for bringing more PA not only into the gamers' lives in particular, but also into the lives of all adolescents and young adults who are leading predominantly sedentary lifestyle. Mobile games based on the Augmented Reality (AR) technology and using GPS positioning can help make exergaming mobile.

Modern smartphones and tablets are powerful enough to support AR. The main feature of Mobile Augmented Reality (MAR) games is that most of them require either moving around while playing or even going outside, walking and exploring large areas. Thus, such games may have a serious potential for helping to increase PA and bring gamers outdoors. Walking is a common, accessible and inexpensive form of PA. It is aerobic and stimulates use of large skeletal muscles, providing numerous health benefits (Hallal et al., 2012). Since walking is a primary requirement of many MAR games, we can assume that such games may have a positive effect on well-being of individuals playing them.

In the recent years many researchers have shown interest in MAR games as an innovative way of promoting PA and some of them developed their own interesting prototypes (Görgu, et al., 2010; Chitaro & Sioni, 2012; Lindeman et al., 2012), but so far there are no comprehensive studies that would actually prove or disprove the effectiveness of such games.

The goal of this research is to study the effectiveness of active MAR games as a tool for increasing PA. The research is divided into two parts – theoretical and practical:

1. The main purpose of the theoretical part is studying the latest researches in Augmented Reality, and MAR games in particular, and analysing related works

about facilitating PA through gaming, in order to understand the current situation in this area.

2. Practical part is aimed at testing one MAR game and receiving participants' opinion regarding the game and the experience they got while playing. Apart from evaluating UX, it is also necessary to measure the activity level of the participants for assessing the impact that the selected MAR game has on increasing PA.

In order to get clear answers from the research, it is important to articulate relevant questions and always keep them in mind during the study. Three main questions have been formulated for this research:

1. What are the main advantages and disadvantages of MAR games compared to traditional computer and video games?

   Revealing possible shortcomings of MAR games is necessary for finding ways of fixing or overcoming them, thus making them better and giving priority in front of computer games.

2. Do active MAR games contribute to increasing the level of PA among its players?

   Before starting the promotion of active MAR games for increasing PA, they actually need to be assessed in terms of providing this PA. It is necessary to find out whether these games are suitable and effective for this purpose or not.

3. What are the motivating triggers that would persuade players to keep on playing MAR games regularly?

   In case of the positive answer for the second question, it will be important that players get accustomed to playing MAR games frequently and even make it a habit, because maintaining active, healthy lifestyle is a matter of sustained efforts.

It is estimated that this research will bring more understanding of experience provided by playing MAR games, and show either their effectiveness or inefficiency in terms of increasing PA. The author intends to use the results of this research in her further studies of exergaming, Augmented Reality and MAR games in particular. In case of positive outcome, it is planned to continue promoting PA through MAR games and develop a new game specially for keeping in shape. The author also expects that this work will draw attention to the problem of sedentary lifestyle and persuade at least one person review his or her unhealthy habits and move actively towards excellent state of health.

1. State of Art

In this chapter, I am going to present and analyse the findings of the theoretical part of my research, where I explored the works and studies related to my thesis.

1.1. Sedentary Life and Game Addiction

Sedentary lifestyle is characterized by the lack of physical activity (PA) in a daily life. It may lead to more serious diseases, like muscle atrophy, obesity, and even depression and infertility. In 2009, physical inactivity was identified as the fourth leading risk factor (after high blood pressure, tobacco use and high blood glucose) for chronic diseases and accounted for more than 3 million preventable deaths (WHO, 2009). According to World Health Organization, 31,1% of worldwide population are physically inactive (roughly 2 billion people), more than 80% of the world's adolescents are not active enough.

There are many methods of measuring PA. One way is to use self-reports and interviews, where people are asked to fill various forms and surveys based on general PA recommendations, different for different age groups. For example, WHO recommends at least 60 minutes of moderate-to-vigorous intensity PA daily for children and adolescents (age group of 5-17 years), at least 150 minutes of moderate intensity (or 75 minutes of vigorous intensity) throughout the week for adults (age group of 18-64 years) and same for adults aged 65 years and above. WHO has also developed the Global Physical Activity Questionnaire (GPAQ) to measure PA in adults (WHO, 2010). Such way is easier to implement, especially when a large sample is considered, but at the same time very subjective and may have reliability issues.

Another way is to directly measure the amount of PA, for example through Heart Rate monitors, accelerometry and calorimetry (Ekelund, 2009). These methods are more complex, make use of various measurement tools and devices and sometimes are harder to implement with big sample, but they also provide more reliable and objective data. Additionally, Tudor-Locke & Basset (2004) developed a scale of measuring PA levels according to the amount of steps that one takes during a day (Table 1). These indices are measured with pedometer and can be considered objective as well, although some inaccuracy may occur due to improper positioning of the pedometer on the body.

Table 1. Activity levels based on the amount of steps taken per day

Steps/day	Activity level
< 2,500	Basal activity
2,500 – 4,999	Limited activity
5,000 – 7,499	Low active
7,500 – 9,999	Somewhat active
10,000 – 12,499	Active
≥ 12,500	Highly active

According to Tudor-Locke & Basset table, it is necessary to make at least 10,000 steps each day in order to lead an active lifestyle. Many fitness organizations, instructors and physicians recommend it to their clients, and some activity trackers, such as Fitbit[1], set it as a default goal. It is interesting to know that initially the concept of 10 000 steps a day was born in Japan in 1965, when a device called *Manpo-kei* (literally meaning "10 000 steps meter") was patented by Yamasa Tokei, a watchmaker (Tudor-Locke, 2003). Thanks to a big promotional campaign for Manpo-kei, nowadays this simple health advice is very well known in Japan, maybe this is why Japanese are considered one of the fittest and physically active nations in the world. However, some recent researches showed that even in Japan people tend to become more physically inactive. Only 36% of men and 28% of women aged 20 years and above exercise at least 30 minutes, twice or more times a week, and in general, Japanese adults takes between 6,200 and 9,700 steps a day. The mean steps in 2008 declined comparing to the peak values in 2003-2005 (Cao, 2015).

There is a similar situation in America. According to Powers Hannley (2014), the number of women in the US leading sedentary lifestyle increased from 19,1% in 1994 to 51,7% in 2010. For men this number increased from 11,4% in 1994 to 43,5% in 2010. Of course, we cannot predict how the situation with sedentary lifestyle will change in the future, but, if we assume that this tendency remains, the number of physically inactive people will only continue to grow in the future. As a result, there are serious risks of ending up with a generation of ill

[1] Fitbit is a company producing wearable sensors and wireless technology for fitness and health. Official website: https://www.fitbit.com

feeble people in the next 20-40 years, not only in the US, but also in other developed countries.

On the bright side, the situation in Estonia is relatively reassuring - only 17% of population are inactive. Thus, Estonia appears in the top three of the most active countries in the world, between Greece (only 16% are inactive) and Netherlands (18% of inactive people) (Thomas, 2012). Still, 17% of Estonian population makes around 220 000 people, that is roughly half of Tallinn's population. Unfortunately, this study does not provide any exact data about specific age and gender characteristics of inactive population in Estonia, however there are some common patterns around the world - level of inactivity grows with age, and women tend to be more physically inactive than men.

The reason for this situation is that many people, in addition to having a confining job in office or in any other movement-limiting environment, also spend their leisure time in a sitting position at home - reading, watching TV, surfing the Internet or playing computer/video games, instead of engaging in outdoor activities or doing sports. We do not see children playing with each other on the playgrounds or in the backyards as often as we used to, because now most of them are hooked to their TV and computer screens, playing games on their computers or video game consoles. Many adults are also fond of such leisure time activity. According to a report by Spil Games[1], more than 1,2 billion people are playing games worldwide (Spil Games, 2013). We already know that about 2 billion people lack PA in their lives, so it is possible that excessive game playing may contribute to such lifestyle at least for half of them.

Just recently, in September 2015, shocking news came from Russia's Republic of Bashkortostan, where a teenager died of thrombosis caused by almost non-stop computer game playing for 22 days (McCrum, 2015). The news said he broke his leg and had to stay at home, so he got bored and eventually became addicted to playing computer. Although the computer game itself cannot be blamed for such tragic outcome, it is obvious that the excessive playing led to the lack of movement, which in turn provoked blood clod. And it is not a single case, there are many stories like that (Rudd, 2012; Twomey, 2016).

[1] Spil Games is a game developing/producing company specializing mainly on free online games. Official website: http://www.spilgames.com/

Fighting game addiction, like any other addiction for that matter, could be a challenging and complicated task. Some game addicts may show aggression and psychotic behavior when facing restriction to play their favorite games and being forced to engage in other less pleasing activities, but what if game playing could be put to a good use. Many researchers have found the effectiveness of computer games for educational purposes, for example, Torrente et al. (2010) note that such games improve students' motivation for learning and also improve their study results. Similarly, we can assume that games for exercising purposes will improve gamers' motivation for getting up from their chairs and sofas, increasing their PA and even improve health condition in a long-term perspective.

1.2. ExerGaming

It is not hard to guess that the term "ExerGaming" consists of two words merged together – "exercise" and "gaming". In some sense, it is a gamification of an exercising process, and gamification is known for its success in encouraging changes in user behaviour (Deterding et al., 2011). Brauner et al. (2013) assume that the role of exergaming is not only in providing an entertaining way of working out and facilitating PA, but also promoting healthy lifestyle, establishing a pattern for healthy behaviour and raising awareness of one's health and physical condition. The potential power of exergaming is based on such psychological principles like performance feedback and rewards/achievement system, self-control and self-efficacy, fun and entertainment (Brauner et al.).

Additionally, an ultimate idea of exergaming makes use of an old principle, very well known and used in psychology for half the century – the Premack principle (Premack, 1959). According to it, engaging in more probable/favourable behaviours (activities) reinforces less probable/favourable behaviours (activities). For example, a trained dog performs tricks for a treat. This principle is also known as "grandma's rule" – *eat your vegetables before having a dessert*. In case of exergaming, gamers are engaged in their favourite activity – playing video games, but unlike with typical sedentary games, they are also forced to perform active physical exercises, which is otherwise not so favourable (Brauner et al.).

The term "exergaming" emerged presumably in the beginning of 21st century, between 2000-2005, when such video games were popularized, although first video games of this genre existed before. In 1987, Exus released the Foot Craz pad controller for Atari 2600[1], and a

[1] Atari 2600 is a home video console, released in 1977, largely popular in the late 70's and early 80's.

year later Nintendo released similar device for their Nintendo Entertainment System (NES)[1], which they called Power Pad (Bogost, 2007). Both pads, despite the differences in look and components, had the same purpose – controlling the game play by stepping on the touch-sensitive buttons (circles). The majority of the games employing such controllers were single-player sports games, mainly running. However, neither of the systems were much successful for long.

Dance Dance Revolution

The first real success of such games came only 10 years later, when Konami introduced Dance Dance Revolution (DDR) in 1998. It was originally released for arcade machines, but later was also ported to Sony PlayStation and other video consoles as well, and has had many update versions since then. DDR is a rhythmic dancing simulator, where player must follow the on-screen indicators and make corresponding moves while standing on the control pad. Such gameplay requires fair amount of physical efforts from the player, and there even was a promotional campaign claiming that DDR is a perfect tool for losing weight and that a certain young woman lost 43 kg simply playing DDR. It is hard to verify this data, but apparently the campaign fulfilled its mission and raised huge interest both in media and among people, resulting in increased sales. Anecdotal market reports suggested that consumers were buying PlayStation consoles, dance pad peripherals and copies of DDR solely for the purpose of exercise (Bogost, 2007). That is how the term "exergaming" was born.

Wii

One of the well-known examples of contemporary exergames is the Wii physical simulation games series (i.e. Wii Sports, Wii Play, Wii Fit and others). First released in 2006, Wii sold millions of copies since then, with some of the games becoming best-selling video games of all time. The main feature of the games is using special equipment bundled with the console, e.g. Wii Remote (in Sports or Play) and Wii Balance Board (in Fit).

Wii Remote is hand-held and is used for various gaming activities, e.g. imitating boxing or playing tennis. Wii Balance Board resembles a body scale; it measures player's weight and center of balance and provides games to work on a body posture. The core mechanics of Wii

[1] Nintendo Entertainment System is an 8-bit home video console, first released in 1983 in Japan under the name "FamiCom" (Family Computer). Was popular in the late 80's and early 90's.

games make use of player's body and allows control of the gameplay through player's physical movements. The general philosophy of Wii exergames is getting the players off their couches and engaging them in an active gameplay. A Nintendo page for Wii Fit[1] calls it a "fun way to get fit."

Kinect

In 2009 Microsoft introduced Project Natal, a motion sensor camera, for their gaming console Xbox 360. A year later it was renamed to Kinect and released for public use. Today it has been improved to the version 2.0 and also works with Xbox One and OS Windows. Unlike Wii that makes use of special controllers, games working with Kinect camera are controlled by gestures, movements and voice. This gives players more freedom and facilitates natural and intuitive interaction. For example, an Xbox One game "Fighter Within" is a martial arts game, where players control their in-game avatars with their own bodies. While the game received quite a lot of negative responses and reviews mainly due to a number of issues with controls, it still shows a great potential for the Kinect-based games.

In 2013 Microsoft published Xbox Fitness, an exclusive service for Xbox One, which is basically a set of exercising videos. User can choose any of the available videos and start exercising following the fitness instructor on screen. The Kinect is used here for reading user's heart rate as well as tracking which muscles and body parts are the most engaged during a particular exercise and provide the user with feedback regarding their performance (Campbell, 2013). To add a gamification factor in order to give users more motivation, Xbox Fitness includes various achievements for each video, generic community scores and opportunity to share results with friends and challenge them to beat their score

1.3. Studies

Although exergames have existed for quite a while, there were no serious studies evaluating their effectiveness in terms of facilitating PA until the 2010's. Graves et al. (2010) performed a lab study where they evaluated physiological cost and enjoyment of adolescents (11-17 years), young adults (21-38 years) and older adults (45-70 years) while playing Wii Fit, compared to usual video gaming, brisk treadmill walking and jogging. They measured various biometrical characteristics of the participants and compared Energy Expenditure

[1] http://www.nintendo.com/games/detail/hoiNtus4JvIcPtP8LQPyud4Kyy393oep

(EE), Heart Rate (HR) and enjoyment of all the activities. Firstly, participants played Tetris, then completed three Wii Fit exercises in each of 4 categories (Yoga, Muscle conditioning, Balance and Aerobics), and lastly they performed walking and jogging on a treadmill. Each of the activities lasted for 10 minutes, and also involved one period of seated rest, which lasted 5 minutes.

The results showed that for all participants, both EE and HR during Wii Fit activities were significantly higher than during sedentary playing, however they were also significantly lower than during treadmill walking and jogging. At the same time, enjoyment was greater for Wii Fit, compared both to sedentary playing, and walking and jogging. Graves et al. consider enjoyment an important determinant, which gives motivation to perform a certain activity. This way, inactive individuals may not see doing regular aerobic exercises as attractive, mainly due to the lack of enjoyment, and eventually lose motivation. On the other hand, exergaming is fun and enjoyable, providing more motivation, and even if it is not as effective as aerobic exercises, it is still better than sedentary games.

Perron, Graham & Hall (2012) also performed a study comparing playing another Wii exergame, "EA Sports Active", with treadmill walking. During this study, 30 adults walked briskly on a treadmill for 30 minutes and then played the game for another 40 minutes. The researchers measured the intensity of both activities with HR monitors, accelerometers and Ratings of Perceived Exertion (RPE) and also asked the participants to rate affect measures on several different scales. They found out that in general, participants had high levels of HR and RPE after playing the exergame, but at the same time, the percentage of moderate-to-higer intensity was bigger for the treadmill. Affect measures were consistent with those results, showing positive affect for both activities, however the enjoyment level was still bigger in the case of exergaming. The authors concluded that the tested game could be a good mode of exercise.

MacArthur et al. (2014) studied children while playing an Xbox 360 Kinect game and playing outdoors. They used three accelerometers (on hip and wrists) to measure the amount of moderate-to-vigorous intensity PA and estimated EE, received during both activities, as well as direct observation to assess the Children's Activity Rating Scale. Children were asked to play "River Rush", a Kinect game where player stands on a raft while it moves down the river and has to control it with her own body movements e.g. move from side to side and jump. The goal is to avoid the obstacles on the way, collect scattered tokens and

earn as many points as possible. The game is aimed at children from the age of 6, helps in developing flexibility and reflexes and according to Elliot (2012) it is also good for hyperactive children. The gaming session lasted for 15 minutes, and outdoor play, conducted in an outdoor playground, took 15 minutes as well. Both the accelerometer data analysis and direct observation results showed that moderate-to-vigorous intensity PA was higher during exergaming session. As a result, the authors consider active video games a good source of PA for young children.

Limitations

Exergaming has a great potential in promoting PA due to its highly motivational factors of enjoyment. Nonetheless, some researchers see several crucial limitations of exergaming. All active video games are tied to a console and TV, and the whole activities of exergaming are limited to indoor use, the living room in particular. The living room is generally an inactive, static space with large heavy furniture that occupies most of the room (Bogost, 2007). exergames require a decent amount of free space so that the players do not get any injuries by accidentally hitting an armchair or a coffee table while exercising. Moreover, some of the games utilize equipment that needs to be placed on the floor under the player, e.g. pad controller or Wii Balance Board, so there must be a considerable amount of free space in front of the TV. Bogost assumes that concerning the size of an average living room, many families would need to move and re-arrange furniture to ensure safe exergaming. Lastly, we should also keep in mind, that not all people have video consoles at their home, preferring PC games instead, and buying a console solely for the purpose of exergaming does not seem so likely.

Several other researchers also see these limitations of exergaming as a substantial issue. For example, Barnett and her colleagues claim that active game playing in a static, confined environment may notably limit opportunities for physical activities and to expand the opportunities of exergaming, it is suggested to bring the gameplay outdoors. They assume that mobile active games, based on a personal mobile device, such as smartphone, can be more effective in facilitating PA, because they remove constraints that limit games to a fixed location (Barnett et al., 2013). They also add that smartphones are universal, used by the majority of people and are well integrated into their daily life. Many researchers have studied the ways of implementing exergaming on mobile platforms and found out that Augmented Reality (AR) has a great potential and is the most suitable technology for that purpose

(Austin et al., 2010; Görgü et al., 2010; Chittaro & Sioni, 2012; Buddharaju & Pamidi, 2013; Mortazavi et al., 2014).

1.4. Augmented Reality in a Nutshell

Before turning to AR-based mobile exergaming it is important to get a brief overview of the technology in question. The best way to define AR is by referring to Ronald Azuma, who can be considered a real "guru" of AR. In his widely cited "Survey of Augmented Reality" (1997) he determines three main characteristics of AR:

1. It combines real and virtual worlds;
2. It is interactive in real time;
3. It is registered in 3 dimensions.

Despite the old publication date, these characteristics still appear to be true and correspond to the present state of the art. In AR, the real world (i.e. reality) is augmented with computer-generated virtual objects, thus the term "augmented reality".

Although the concept of AR existed since the late 50's, the term itself emerged only in 1990, when a Boeing researcher, Tom Caudell, mentioned it for the first time in his paper (Grover, 2014). However, for quite a long time AR did not pretty much leave the lab boundaries, mainly due to its expensive and bulky equipment, not suitable for common end-users.

In 1996 Jun Rekimoto invents first 2D matrix markers for registering and positioning AR objects (Rekimoto, 1998). Before that, AR systems used sensor-based tracking, but such method was often inaccurate, therefore the need for new, more effective methods emerged. Rekimoto proposed the 2D matrix markers as a new alternative. In essence, these markers are square-shaped barcodes, recognizable by the AR system. The system seeks the matrix codes in the captured video, identifies their value and overlays corresponding computer graphics on the real world image (Figure 1).

Figure 1. Marker-based AR[1].

[1] Image courtesy of http://www.alife-studios.com/

The invention of 2D markers is an important point on the AR timeline, because nowadays they are widely used for various purposes (e.g. advertising in magazines or interactive content in children's books), forming a separate category of AR, called "Marker-based AR". The main advantage of 2D markers is that they can be easily printed with usual laser or inkjet printer and placed on any physical surface or object.

Later, in 1999 Hirokazu Kato from the Nara Institute of Science and Technology released ARToolKit, a software library for building AR applications. It provides computer vision algorithms to enable camera calibration and tracking of physical markers in real time. It is an open source project, which makes it freely available for any developer. It was the first prerequisite for bringing AR to masses. After another 10 years, in 2009, Tomohiko Koyama a.k.a. Saqoosha, who was a Flash developer in Katamari Inc., Japan, ported ARToolKit to Adobe Flash, bringing AR to the web browser (Sung, 2011; Grover, 2014) and finally letting it go mainstream.

Many scholars, developers and simply tech-enthusiasts employed ARToolKit in their projects. In 2001-2004 there was a European project called ARCO (Augmented Representation of Cultural Objects) where AR and VR were used for visualisation of museum artefacts. The idea of the project was to enable virtual exhibitions and interaction with virtual exhibits in the context of real-world environment (Wojciechowski et al., 2003). Jiang & Kuang (2015) describe their research on how to develop a system simulating wearing of virtual jewellery based on ARToolKit. They believe that such system can enrich online shopping experience and help customers to try on jewellery and see how it will look on them before purchase.

The emergence of smartphones opened a new era for AR, making it fully accessible for every smartphone user. Initially ARToolKit was available for Microsoft Windows, Mac OS X and Linux, but later it was also ported to Symbian, Windows Phone, iPhone and Android to support mobile AR applications.

In 2012 ARToolKit has also become available as a plugin for Unity, a game engine for developing 2D and 3D games, which made it possible to create powerful and full-featured AR games and apps both for desktop and mobile platforms (Inglobe, 2012). For example, Kim et al. (2014) created a new version of their old mobile exergame "Calory Battle AR" using Unity 3D and claimed that it simplified the development process comparing with programming without using a third party equipment.

Augmented Reality has a broad area of application, from education, entertainment and retailing to military and medical use, depending on the display. Kent (2012) distinguishes three major display techniques for AR: Head-Mounted Display (HMD), handheld displays and spatial displays, but it would also be appropriate to add static displays into this list:

1. **HMD** (Figure 2-a) is also known as "wearable AR" or "AR glasses". HMD is divided into two types: optical see-through (OST) and video see-through (VST). In OST the user sees the world through transparent glass, and AR content is displayed on this glass, thereby optically combining the real and virtual views directly into the user's eyes (Rolland & Fuchs, 2000). In VST the real world view is captured on camera, AR content is electronically integrated into this captured video, creating an illusion of AR, and the user sees it in real time through the camera. OST is a more natural way of augmenting reality, however it is also more challenging in implementation (Hartley, 2012), therefore, VST is more common nowadays. For example, some researchers describe possible perspectives of using it in medical purposes to assist surgeries (Keller, State & Fuchs, 2008; Ferrari, Pisa & Mosca, 2011). Another well-known example of HMD that was planned for commercial use is Google Glass, but the project was stalled due to a number of safety and privacy concerns. People using Glass in an anti-social way (e.g. surreptitious video and audio recordings) were mockingly named "Glassholes" and this term was quickly picked up by media, turning it into black PR (Crothers, 2015). Although according to some sources, Google has not given up on Glass and is working on its new version targeted mainly at small businesses, known as Project Aura (Maina, 2015).
2. **Spatial display** (Figure 2-b) uses digital projector and 3D Kinect camera to impose graphical image onto fixed surfaces (looks like a hologram in some way). A good example of this kind of display is an "AR Sandbox" which creates virtual topography models on a physical sandbox for various simulations. Spatial display literally brings virtual objects to the real world, instead of just rendering them on the screen.
3. **Static display** (Figure 2-c) is any LCD, PC or laptop screen, equipped with a web-camera and pre-installed software, but often it also works directly from browser. This technique mainly employs 2D markers that have to be either downloaded and printed out manually by the user, or are already printed on some product, in advertisement, in magazine etc.

4. **Handheld display** (Figure 2-d) is any mobile device, such as smartphone or tablet, with a digital camera. It works in a similar way to HMD that uses VST approach. The device's camera captures the real-world view, then the captured image/video is augmented with graphical elements and displayed on the screen. Some AR apps require markers for displaying virtual content, while others employ so-called natural features tracking (e.g. based on geolocation).

Figure 2. Types of AR displays: (a) HMD (Google Glass)[1]; (b) Spatial display (AR Sandbox)[2]; (c) Static display (Popar 3D AR book)[3]; (d) Handheld display (GlorAR 3D AR Browser)[4].

Spatial displays are quite cumbersome and costly, they require a lot of hardware (Kinect camera, projector etc.), special software and other components (e.g. markers), which is mostly used by specialists in lab environment or in museums and various exhibitions. It is hardly accessible for the majority of common people to use in their home environment.

Static displays can be widely used both in public sector (e.g. interactive advertisement displays) and at home. If we consider domestic static displays, they do not require any expensive equipment - almost everyone have computers, webcams and printers at home. However, due to their static quality, they can be used only indoors.

[1] Image courtesy of http://www.cyborg-artisan.net/
[2] Image courtesy of http://idav.ucdavis.edu/
[3] Image courtesy of http://www.geekalerts.com/
[4] Image courtesy of http://www.realareal.com/

Modern HMDs, even though significantly advanced comparing to the early prototypes of the previous century, still have many issues and not many have managed to overpass the "demo ware" stage and enter the wide market (Guttag, 2015), and even those that are currently available on the market, are quite expensive and bulky. Nevertheless, some experts claim that in the not so distant future, HMDs (namely so-called "AR Glasses") could be the user interface of choice and will even gradually replace the conventional handheld smartphones (Mirza & Sarayeddine, 2012), the question is, when does this future begin.

Handheld displays combine the affordability of static displays and the mobility of HMDs. Smartphones and tablets are commonly used nowadays, and there are many AR apps and games available for free or for a small price in App Store or Play Market, that can be downloaded and installed like any other mobile app or game. For now, while HMDs are still waiting for their hour of triumph, handheld displays are the best option for MAR, and active MAR games in particular.

However, comparing to HMD, handheld displays have some disadvantages as well. Firstly, users need to hold the mobile device in front of them all the time, and it physically constraints their hands, unlike HMD, which is worn on the head and leaves the hands free, making its use more natural. Another disadvantage of mobile devices is their small screens. Even if we take a tablet with large 10.1'' display, the user will still see the augmented world through the tablet screen, which prevents full immersion like in HMD (Kent, 2012).

Perhaps in the future, when HMDs finally enter the market, they will be used along with smartphones, becoming their extension, similar to smart watches today. It could provide new opportunities for mobile games of the future, where HMD serves as a screen for displaying the game, player is in the center of the gameplay, acting as an avatar, and smartphone can act as an additional game controller e.g. a gun for shooting enemies in the game. Last year in January, International CES 2015[1] took place in Las Vegas, where ImmersiON-VRelia[2] presented their Virtual Reality (VR) HMD "The GO" bundled with a gamepad controller (Figure 3). This HMD turns any smartphone with a display up to 6'' into personal VR glasses. User simply needs to insert a smartphone into the HMD and adjust optical lenses to

[1] International Consumer Electronics Show (CES) is the annual consumer technology exhibition gathering all tech innovators from all over the world for showcasing their latest inventions. Official website: http://www.cesweb.org/

[2] ImmersiON-VRelia is a company developing virtual reality products and services. Official website: http://immersionvrelia.com/

his or her eyesight. It is a big plus for people with eyesight problems, because they can get a clear and sharp image without wearing prescription glasses. Another advantage is its considerable affordability, comparing to other VR glasses (e.g. Oculus Rift). One can order the full set of HMD and controller from the official website just for 139.99$. ImmersiON-VRelia also develops various mobile VR applications to use along with their HMD. Taking into account that "The GO" does not cover the phone camera, it is possible to capture video, thus it also provides an opportunity for implementing AR. As a result, "The GO" becomes "2 in 1": both VR and AR glasses. In the future ImmersiON-VRelia GO could become a very useful tool for experimenting with active MAR games.

Figure 3.. ImmersiON-VRelia GO HMD and gamepad controller[1].

1.5. Augmented Reality Out-of-Doors

Just like the emergence of mobile phones freed us from landline telephones, allowing phone calls wherever we are - at home, at work or at a picnic in the park, advancement of smartphones gave a great opportunity of bringing AR outdoors. Of course, such attempts have been made long before the invasion of smartphones, by means of HMDs, although the bulky and heavy-weight devices of those times made it extremely difficult to move around, making the user look like a cyborg and certainly attracting curious glances.

The Pioneer of Outdoor AR

In 2000, Professor Bruce H. Thomas and his students at the University of South Australia started a project called ARQuake. It was an AR version of Quake, a first-person 3D shooter game popular in the late 90's, and was meant both for indoor and outdoor playing (Thomas et al., 2000). In ARQuake player must move around in the real world, wearing special equipment that includes HMD, mobile computer worn on the back and two-button input device that was later substituted with a gun controller, and shoot virtual monsters (Figure 4).

[1] Image courtesy of http://immersionvrelia.com/

The monsters and other graphical elements of the game are superimposed over the picture of the real world that the player sees through the HMD. The game uses original Quake source code that is freely available now, although the developers brought in few modifications and removed some of the elements that were obviously difficult or impossible to implement in the physical world.

Figure 4. Left: One of the first versions of ARQuake architecture. Right: ARQuake Gameplay[1].

The original architecture of ARQuake was quite ponderous and expensive, but the team kept on improving it and by 2006 it became much miniaturized and light-weight, although still hardly affordable for personal use at home. However, the authors did not intend to commercialize their product anyway and developed it solely for the research purpose. As a result, ARQuake has become the first fully working AR game created for outdoor use and it has generated some interest in the AR world (Kent, 2012). Moreover, ARQuake not only became the pioneer of outdoor AR, but also opened opportunities for outdoor exergaming. Essentially, it demonstrated the basic mechanics for active MAR games: player's body is used instead of an avatar; gameplay is brought outside, into the physical world; player is required to walk while playing, at the same time engaging in a PA.

Location-Based AR

We already know that Jun Rekimoto invented 2D matrix markers, giving birth to marker-based AR. It is quite an accurate and easily implemented method for positioning AR content, however, it is not very suitable for outdoor use, when a large area is considered.

Therefore, many MAR applications and games use location-based method in their architecture. Location-based (or sensor-based) AR makes use of various sensors, mainly GPS, accelerometer and compass (Geiger et al., 2011). All of them are integrated in modern

[1] Images courtesy of http://wearables.unisa.edu.au/

smartphones and tablets. The GPS sensor is used for acquiring geolocation of the device, to know the exact position of the user. The accelerometer provides data for determining the current orientation of the device (vertical, horizontal or oblique). The compass sensor is needed to detect in which direction the user is facing and/or moving. All this data helps the AR system in generating particular graphical content, corresponding to the user's current location, making it context-aware.

Sensors have been used in AR for a long time, and there have been attempts in implementing location-based AR in early personal mobile devices, such as pocket PCs, Personal Digital Assistants (PDAs) and cell-phones (Wagner & Schmalstieg, 2009). However, they were not capable enough to provide full-fledged AR experience and failed to push it further to mass-market, although the foundation has been laid. It was after the introduction of first iPhone in 2007 and Android phone in 2008, that the efficient implementation of location-based AR in mobile devices became possible.

Mobile AR Apps

AR finds a broad area of application in modern mobile devices – smartphones and tablets. Below are just some of the most popular or interesting examples.

Wikitude

Wikitude was the first publicly available mobile AR browser using location-based approach. It was created in 2008 by a group of Austrian developers and initially released for Android (G1 phone, as it was called back then), but later was also ported to other mobile platforms. Nowadays it can be downloaded for free at Google Play Market and App Store, and serves as a tool for viewing AR content, both marker-based and location-based.

One of the first and most popular location-based Wikitude apps is AR Travel Guide, which was quite a break-through in MAR of those times. Based on data acquired by GPS, compass and accelerometer, Wikitude Travel Guide augments the real-world view with useful information about user's surroundings, such as points of interest (POI), descriptions of historical buildings, hotels, restaurants etc. The latest version of Wikitude uses Wikipedia, Yelp, Trip Advisor and other services to display this information (Veronica, 2012).

Another notable app by Wikitude is Wikitude Drive, that was released 2 years later, in 2010, and has also become a pioneer of some sort, being the first AR turn-by-turn navigation app (Goodwin, 2010). This app looks and works exactly like a GPS navigator in cars, overlaying the view of the road with computer-generated turn-by-turn directions in real time.

Layar

One more popular mobile AR browser was developed in 2009 in Netherlands, a year later after the first release of Wikitude, and it works in a similar way, displaying digital content based on user's location. Data comes in the form of so-called "Geo Layers", thus the app name. User can browse through these layers to find various POIs nearby such as ATMs, real estate, restaurants and so on. By July 2010, the number of layers has reached 1000 and continued to grow since then. There have been over 6,000 layers as of March 2014 (Woods, 2014). In the same year Layar announced the release of their AR app for Google Glass, although it is still being in a beta version, since the Glass project itself is surrounded by vagueness.

Nowadays there is quite a big variety of apps like Wikitude and Layar, which also provide augmented information about various POIs, for example, Acrossair, PanicAR, Yelp Monocle or Field Trip.

Augmented Car Finder

Apart from displaying POIs, location-based AR has other as well. One of them is Augmented Car Finder, an app that helps user to find his or her car, if for some reason they forgot where they parked it, or simply in case of parking in large parking areas such as stadiums, concert halls and others. Before leaving the car, the user has to tag it through the app, and then the app creates a marker with the date and time of tagging, address and distance to the marker. There are two view modes – map and camera. In the map view, the user sees the car location on the map, and in the camera view a graphical arrow, pointing in the direction of the car is displayed. Apparently, this app can be used for finding anything else, not just a car. For example, some particular place in an unfamiliar area, where the user has to return after a while. Currently this app is available only for iPhone, but there is also a similar app called Car Finder AR for Android.

Lookator

Another interesting example is Lookator, an app that finds nearby Wi-Fi hotspots and augments them in the user's camera view. It also provides information about distance to the particular Wi-Fi spot, signal strength and whether it is password-protected or not. Combined with Wefi, the database of free Wi-Fi hotspots, it can also display all the hotspots being out of range.

Walgreens app

Walgreens is the biggest drug retailing chain in the US, and they created their namesake app that not only reminds the user about taking pills time, tracks prescription history and more, but also displays nearby stores and helps locating necessary items in store through AR navigation assistant. The app also provides special promotions and suggests products, augmenting them in the camera view.

1.6. Apps and Games Facilitating Physical Activity

Thanks to all the features of modern smartphones (i.e. GPS, compass, accelerometer) it is now possible to create location-aware apps and games and encourage users to go outside and move, engaging in physical activities.

GPS Drawing

There are many mobile apps such as Strava or Google Fit, which utilize GPS navigators to record and display user's tracks on map. Usually sportsmen and bicyclers use such apps to save and view their running/cycling paths, but lately some creative people started using it to draw doodles. This activity was named GPS Art or GPS Drawing. Different artists use different approaches, some improvise on the go, others plan their route beforehand, by analysing the selected area and creating blueprints of their future GPS doodle. FigureRunning, an application developed especially for this purpose, allows users to choose different pencil colours for different lines, creating multi-coloured doodles and also select "No Pencil" option if they do not want to record a certain track (e.g. when different details of the doodle are in different places and should not be connected with each other) (Figure 5). It is a very interesting new phenomena that combines traveling and fitness with art and technology.

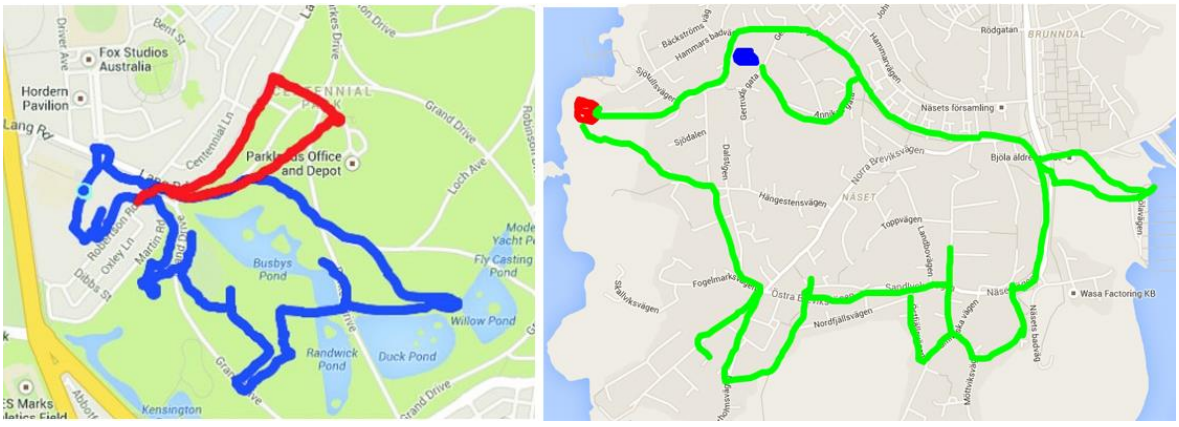

Figure 5. Examples of GPS drawings done with FigureRunning app. Courtesy of figurerunning.com

Loquiz

Scavenger hunt games have been around for a long time. They can be played for fun at parties, used for team building in companies, or for tourists as a form of alternative, gamified sightseeing. Loquiz takes it to the next level by providing a mobile platform for creating such games in smartphones and tablets. Game moderator can create a game by placing pins on a map in certain locations and add questions for each pin along with clues, hints, photos and even videos. Game participants in teams of 3 to 5 members have to follow the map, move from pin to pin (in order defined by a moderator) and answer the questions. The app was developed in Estonia and became quite popular in various traveling agencies and companies providing outdoor/recreation activities in Baltic states and Scandinavia, as well as other countries.

Avastusrada

The project Avastusrada ("Discovery Trail" in Estonian), created by TLU's Institute of Ecology and Institute of Informatics is not entirely an app, but still it is mobile (works from smartphone's browser), and it has similar ideas with Loquiz games. Participants should walk in real world following predefined paths and reach target locations shown on the map in a certain order. Each location has its own instructions (e.g. question or further directions), which can be accessed only when the player is close enough to this location. Most of the trails are located in nature centres all over Estonia and the main purpose of the project is to educate people, especially school students, about nature and environment and how important it is to take care of it.

Temple Treasure Hunt Game

Another mobile game inspired by scavenger hunting. There are three modes in the game – Outdoor – Single Player, Outdoor – Multiplayer and Indoor – Multiplayer. The game story is based on Indian mythology, including several ancient Indian gods and characters as Treasure Guardians. The player's aim is to find the Treasure buried in the Shiva Temple, by following the so-called Treasure Trails, automatically generated by the game (Figure 6).

There are several Guardians standing on the Trail. Locating first Guardian gives a clue to the next Guardian's location and so on, until the last Guardian gives out the location of the Shiva Temple. When the player comes close to the Guardian, he or she needs to press the "Locate Guardian" button. The game then calculates if the player's location really matches the Guardian's location, and, in case of confirmation, the camera view turns on (Figure 7). The player needs to find the Guardian in the camera view and tap on him in order to get the

next Treasure Trail. The game has a time limit, so one must hurry to find the Treasure in time.

The developers believe that Temple Treasure can help in staying fit, since uncovering Treasure Trails every day will be a fun walking exercise (ThoughtShastra, 2013). The game story and idea are really original and innovative in some way, but unfortunately it gives a feeling of incompleteness, because the design looks slightly rough and amateur. Perhaps it was the reason the game did not get much recognition among the smartphone users.

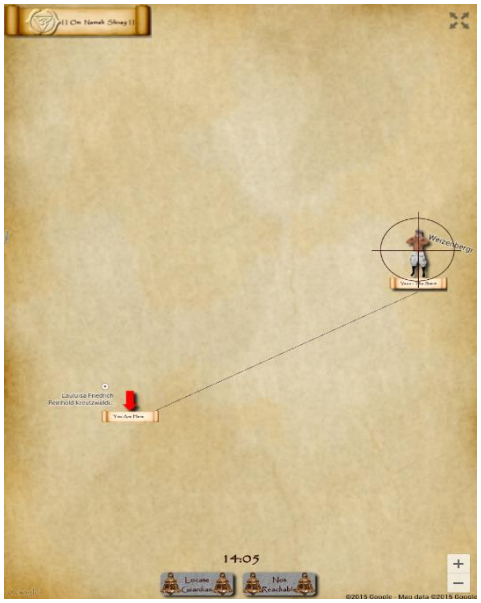

Figure 6. Temple Treasure - map with a Treasure Trail.

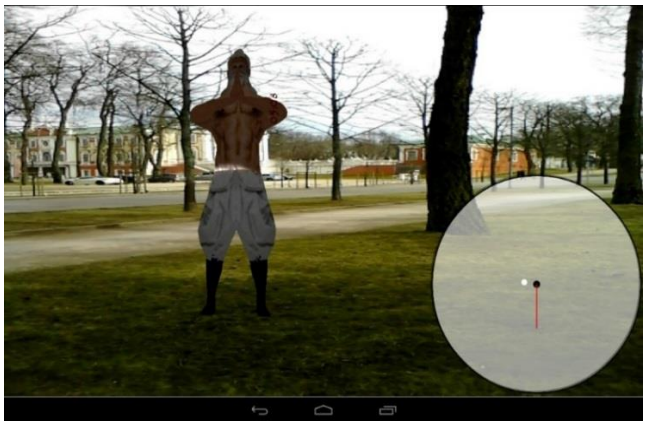

Figure 7. Temple Treasure - camera view and the AR Guardian.

Ingress

Ingress fills the streets with mysterious energy, known as Exotic Matter, seeping through Portals, scattered all over the Earth (Figure 8). The Portals are created by players. To suggest a new Portal one needs to take a photo of a desired place, monument, building or object, give it a name and short description, and submit via the official game site *ingress.com*. There is certain criteria for a Portal, for example, it has to be unique and publicly accessible, and should not include private residential properties, primary/secondary schools, hospitals and fire/police stations. The Portals can be found at the monuments, notable buildings and other places of cultural significance or interest (Figure 9).

Before starting the game, players (referred to as "Agents") are asked to choose a faction. The Enlightened try to help the Exotic Matter to infiltrate our world, believing that it will bring enlightment and take humans to the next level of evolution. The Resistance, on the contrary, sees danger in the unknown energy, thinking that it threatens the very existence of the human

kind, and therefore its invasion must be stopped. The Agents from different factions compete for controlling the Portals. Green Portals are controlled by the Enlightened, Blue Portals belong to the Resistance, and Grey Portals (also called "ghost" portals) are currently unclaimed by either faction. In order to interact with a Portal player needs to walk close enough to its physical location, so that it appears within the player's action range.

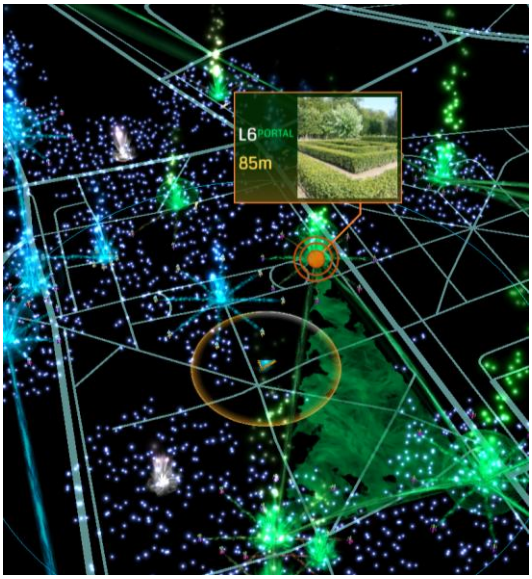

Figure 8. Ingress - map with Portals. Player is represented with an arrow and an action range, the area where the player can interact with Portals or dropped items.

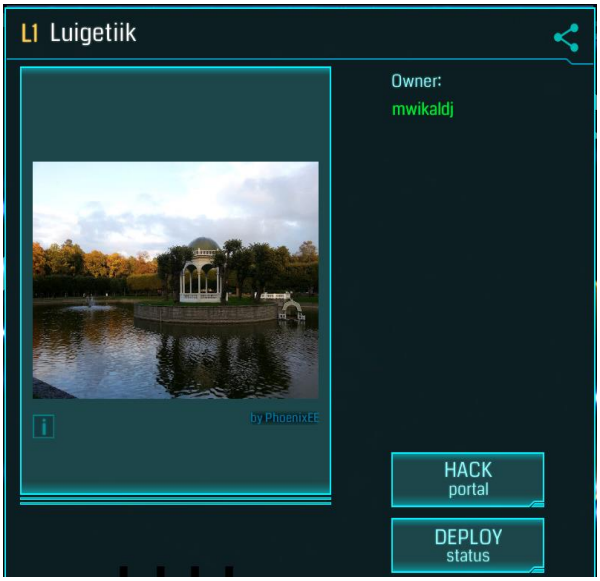

Figure 9. Ingress – example of a Portal found at the Swan Pond in the Kadriorg Park in Tallinn.

Ingress not only urges players to walk, but also lets them explore the surroundings in a completely new way, discovering interesting buildings and objects around them that they have not been aware of, or might not have paid attention otherwise.

GotchApp – Keep on Moving!

This game is a mix of two games that everyone must have played as a child - tag and hide & seek. The player becomes a spy and her goal is to find spy drones and checkpoints on the map and locate and tag them in the real world (Figure 10). If there are other people playing this game nearby, they will also be displayed on the map, and player needs to try to either avoid them so as not to be caught, or get closer and tag them before they spot and tag her. There is also a leaderboard that can be filtered by country and time period, displaying the top 10 of players with best scores.

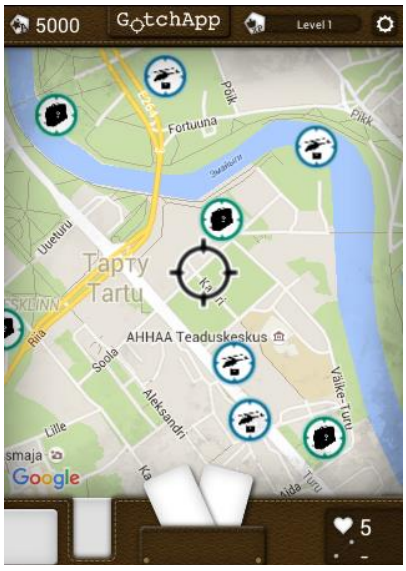

Figure 10. GotchApp – map showing nearby spy drones and checkpoints.

Figure 11. Home Invasion - Satellite map.

Home Invasion

In this game aliens invade the Earth and player becomes one of the aliens whose task is to destroy all the targets in the neighbourhood. Targets are represented as green dots and are placed on the map with a satellite view (Figure 11). In order to destroy those targets, player has to walk outside and, by following the map, get close to a target in real world so that it appears in her laser range. Player gets points for every destroyed target and thus progresses in the game. There are also military tanks scouting the area and it is important not to get inside their fire range, or else they will destroy the player.

SpecTrek

SpecTrek sends players on an exciting ghost hunt, where they need to locate and catch virtual ghosts in the real world within a limited amount of time. There are three time modes by default: Short (15 minutes), Medium (45 minutes) and Long (2 hours), but player can change the duration of each mode in settings. The radius of the hunting area and the amount of ghosts also depend on this. SpecTrek also makes use of accelerometer, switching from map view while in horizontal position to camera view (so-called scanner mode) when held vertically. Map shows the hunting area radius, player's position and locations of the ghosts (Figure 12).

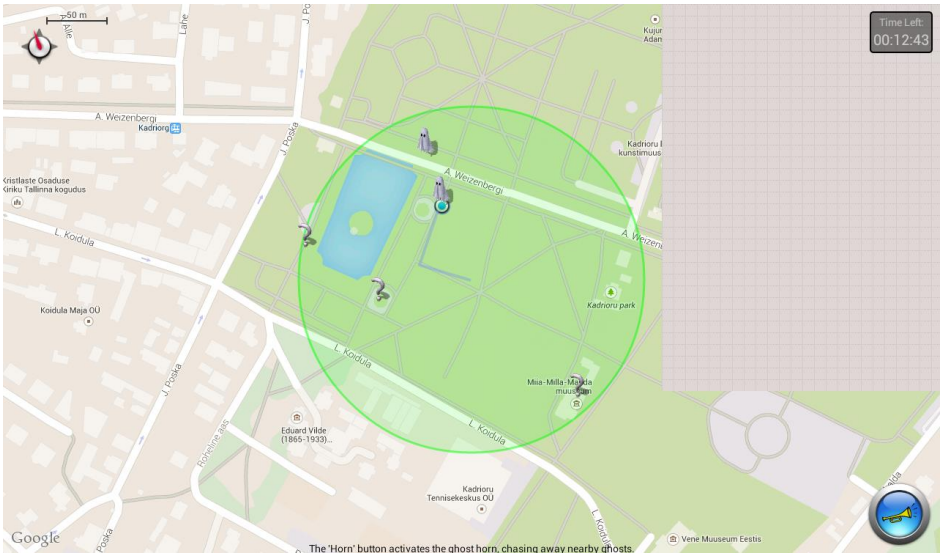

Figure 12. SpecTrek - map with ghosts scattered over the hunting area (green circle).

Scanner allows looking at the surrounding area through the camera and see augmented ghosts (Figure 13), and catch them, if they are in range. Player also can encounter hidden gift boxes with bonuses along the way. Additionally there are statistics, various achievements and awards.

Figure 13. SpecTrek – scanner mode, where a virtual ghost is augmented into camera view.

The game's tagline is "Protect the world and keep in shape!" This indicates that the developers actually intended to motivate potential players for physical exercising with their game, and it might be indeed effective in facilitating PA, because the players have to locate ghosts in quite a large area, and since the time is limited, sometimes they would need to rush in order to complete the task in time.

Zombies, Run!

As the developers of this game called it, Zombies, Run! is a "running game and audio adventure", and it is intended as a fitness gamification tool. It is not AR-based per se, but it still augments the reality with audio input. The goal of the player is to run and collect supplies for the city population surviving in zombie apocalypse. The player will hear instructions in the form of voice recordings from her team through the headphones. Moreover there are also sounds of zombies grumbling and groaning behind the player's back, so he also has to run away from them and avoid being caught and eaten.

It is also worth noting, that three of the described games (Temple Treasure, SpecTrek and Zombies, Run!) are found in the "Health and Fitness" category in Google Play Market, which shows the emerging tendency for fitness-oriented mobile games. Unfortunately, for now there are not so many good, working mobile games, providing seamless physical exercising activities. On the other hand, this means a vast field of open opportunities for

developers to produce new, original and innovative mobile exergames that can become a good alternative for casual mobile games available today in big quantities.

1.7. Mobile ExerGaming

When thinking about transferring exergaming to mobile platforms such as smartphones, and extending it to the outdoor environment, many researchers turn to the Augmented Reality (AR) technology. There is still no evident agreement on how to define the new concept, some researchers call it Location-Based exergaming (Marins et al., 2011; Chittaro & Sioni, 2012), others refer to it as Mobile exergames (Austin et al., 2010; Mortazavi et al., 2014). Görgü et al. (2010) in particular proposed a concept of FreeGaming, and although the term itself did not seem to gain ground among other researchers, its general notions illustrate the main idea of mobile exergaming very well.

"Free" not in the context of money (i.e. without charge), but in the sense that it liberates the gaming process from limitations related to console or PC, so that it is not confined by the boundaries of the living room. The main idea of FreeGaming is to use player's own body instead of a virtual avatar, and rather than exploring a virtual world in a computer game, the player can explore the real world, augmented with graphical overlay, through his or her smartphone camera, by the means of AR technology. The authors emphasize four characteristics of FreeGaming:

1. Mobile (enabling outdoor gameplay can be achieved by using mobile devices, such as smartphones. FreeGaming adds mobility to exergaming, which gives opportunity for increasing the effects of PA).
2. Augmented (AR technology is used to turn the real world around us into the game environment, where the players themselves act as the game protagonists, instead of just controlling the in-game avatars).
3. Collaborative (FreeGaming assumes multiplayer mode, where a certain number of players can simultaneously participate in the gaming process. This social aspect of FreeGaming may have a crucial impact on its effectiveness, because it is believed that social interaction positively affects the player's involvement in the game and motivation to play (Payton et al., 2011)).
4. Adaptive (since the gameplay is mobile and ubiquitous and brought outdoors, the game must be able to adapt to the constantly changing environment. This can be

achieved by using Intelligent Agents (IA) for integrating multiple sensors (e.g. camera, GPS, accelerometer).

Prototypes and Studies

Further, Görgu et al. introduce the FreeGaming system that can be used as a platform for designing mobile exergames. As a proof of its capability, they also present a prototype game, where the player gets objectives and needs to move to certain pre-defined locations in the neighbourhood in order to accomplish them. In a way, this resembles a scavenger hunt. Although the game is a demo version and it does not utilize the FreeGaming concept in its full power, the authors believe that in the future it is possible to employ various sensors, e.g. Heart Rate to control the player's physical performance and generate personalized objectives based on this data, as well as player's age, height, weight and other characteristics.

Some other researchers also addressed mobile exergaming as an alternative to console-tied exergaming and developed their own game prototypes for facilitating PA. For example, Marins et al. (2011) developed a mobile running game SmartRabbit for Android, where players need to run certain distances as fast as possible and can also compete with friends and other players worldwide. The authors believe that their game will encourage people to practice physical activities, however no user studies were performed or described, so it is hard to say whether the game is indeed efficient and motivating.

Few years ago, a student from TLU also promoted an idea of mobile applications aimed at facilitating outdoor physical activities. In her Master's thesis Tamm (2014) describes the process of design and development of a mobile game prototype called "Walk with me". It is not actually an exergame, it serves more as an accompaniment for a walking activity alone or with friends, although it still contributes to providing physical activity, but in a more relaxing way. Moreover, the game is also educating – it helps its players to find and see new interesting details in things and objects that may seem ordinary at the first glance. There were no studies evaluating the game in terms of PA, but interviews with the participants who took part in user study and prototype testing showed that people generally enjoyed the gameplay and claimed that the game would give them more reasons to go out and walk. They would also like to see such features like tracking time, calories or steps integrated in the game, which indicates that they want not only engage in PA, but also be able to see how their health benefits from it.

Another group of researchers, Lindeman et al. (2012) designed an AR game, GeoBoids, where they incorporate video see-through technique to display geometric creatures called GeoBoids in phone's camera view, and player's goal is to capture them (so-called Arcade Mode). There is also a map view, where player can see where the nearby GeoBoids are (randomly generated) on the map and has to walk to their locations in the real world (Field Mode).

The game is similar to SpecTrek described earlier, but also has some new interesting features, e.g. use of spatialized audio (audio is processed in a way that it creates an illusion of 3D environment, which can increase the level of presence and immersion) and audio input in a form of whistle. Player can whistle into the phone to scare GeoBoids off, causing them to "flock" and making it easier to catch them. The game determines on-screen audio level in order to provide immediate feedback whether the whistle is performed with a correct pitch and duration. Such new form of game interaction seemed confusing to most of the participants who tested the game, because some of them did not understand how it worked or what it was used for, and some simply could not whistle at all and suggested other types of audio input like blowing or shouting. Apart from that the prototype game received quite a positive feedback, however the authors evaluated only the technical elements of the game e.g. game mechanics and GUI, and did not assess user experience and exergaming aspects i.e. measuring PA during the gameplay, although initially they claimed it as a mobile exergame.

One more game prototype, LocoSnake, is presented by Chittaro & Sioni (2012). That game is inspired by the classic old mobile game Snake, where player controls a snake on the screen, collects fruits in order to get points and has to avoid hitting the field borders or snake's own body. In LocoSnake the player actually becomes the snake and has to walk around in the real world in order to control the snake on screen. The rest of the gameplay is similar to the original Snake game, with the only exception that the game does not end when the player hits the borders. Before starting the game player is asked to create a playing field in form of a square or a rectangle e.g. on a football field or a large lawn. The field borders are marked on a satellite map. It is also possible to name and save a new field in order to play it again later. There is a time limit of 5 minutes for each game level.

During their user study the authors evaluated enjoyment provided by LocoSnake with Player Enjoyment Scale (PES) and several open questions. Furthermore, they compared playing the

game with simple walking and measured walking speed, PA enjoyment using Physical Activity Enjoyment Scale (PACES) and the levels of physical exertion using Borg's Rating of Perceived Exertion (RPE). They also wanted to find out whether there are any relations among participants' lifestyle, exergame enjoyment and attitudes towards walking.

The results showed that the participants' perceived exertion while playing LocoSnake was greater than during walking, but the walking speed was not very much different. People whose lifestyle was more sedentary tended to enjoy PA more while playing the game, whereas more physically active participants stated that the game required a lot of focus thus making walking during the game less pleasant. Overall PES results showed that the participants enjoyed the game. In particular, they liked the link between the game and the real world, and connection of PA with gaming.

Austin et al. (2010) also developed and tested their own mobile exergame prototype, which they called World of Workout. It is an RPG with a linear quest-based story, where players have to physically walk in order to complete quests and reach the game's goals. World of Workout detects and records player's steps and gives XP points accordingly. During a case study the heart rates of the participants raised to some extent, but it gives little information about physical extortion. Additionally they found out that it is easy to cheat with such pedometer-based approach, since players can simply shake the device and it will be recognized as taking steps. Overall the participants were positive about World of Workout and claimed it would motivate them to play it along with their regular walking. They also liked the general concept of the game.

It is evident that mobile exergaming, especially based on AR, attracted many researchers and game developers, but creating such games that would be both efficient in terms of facilitating PA, and fun and motivating for playing on a regular basis, seems to be rather problematic and challenging.

2. Methodology

The aim of this case study is to test a mobile AR-based game, measure the level of PA that it generates in players and find out whether it is effective as an exergame. Additionally it is important to discover motivational factors that the game either has or lacks, in order to understand how to make such games more attractive for the users.

Observation will be implemented during the game testing sessions. The researcher/moderator is going to watch the participants while they are playing and take relevant notes to analyse afterwards. The participants will also be asked to think aloud while playing and express their emotions, thoughts and opinions about the game and the process. Such empirical participatory research is useful for gaining valuable insights into the game from the players' perspective.

After the testing session, a short interview will be conducted with each participant to learn about his or her impression of the game and gathered experience. For a more in-depth analysis of user experience, Game Experience Questionnaire (GEQ) will be sent by e-mail to all participants. It is a very handy and comprehensible method for evaluating user experience in games. GEQ will be described with more details further in this study.

2.1. Choosing a Game for the Case Study

For this study, it was important to differentiate one particular category of mobile games based on AR – active MAR games, because the primary aim of this thesis is to find whether these games are able to contribute into active lifestyle, and it is necessary to select the most suiting game for the testing. Key features of active MAR games are listed below in order to give a clear explanation of what exactly is expected from them:

- Location-based;
- Gameplay is brought outdoors and spread across considerably large area;
- Player is required to move actively during the gameplay;
- Social context is preferable e.g. competition/collaboration opportunity, ability to share and compare results with other players, leader boards etc.

It was already mentioned in the previous chapter, that location-based approach in AR is more suitable for outdoor-intended applications, and, naturally, it is essential for active MAR games as well. Such games must be able to quickly adapt to the constantly changing

environment around the player and build their gameplay accordingly. Playing outdoors has many benefits: furniture or walls do not restrict the player's movement, so the playing area is literally unbounded, which gives more freedom to PA, and of course, any activity in the open air is beneficial for health and enriches the body with oxygen. Thomas (2012) called walking an ideal and natural form of exercise that anyone can routinely participate in. Moreover, it also provides a convenient way of measuring the level of PA based on the amount of walked steps that can be compared to the Tudor-Locke & Basset table of activity levels mentioned in the first chapter (Table 1).

Social context is important both for attracting new players to playing the game and for motivating the existing players to keep on playing the game. Playing together with friends is more exciting and engaging than playing alone, because being able to compare results with friends might urge players to try harder and improve their results to reach the top of the leader boards. Same as in sports, competitiveness in active games is a significant factor for encouraging better performance. However, at this stage, the social context can be disregarded, because the main goal is to measure effectiveness in raising PA, and competitiveness is not important.

Most notable games existing on the market were already briefly introduced in the previous chapter, and candidates for the testing were also selected among those games. Although GPS Drawing encourages walking, it cannot be considered as a game and GEQ would be inapplicable. Loquiz is more of a tool for creating games and opens a whole new area of investigation for future researches, but at this point it was desirable to use a ready-made stand-alone game. Both GotchApp and Home Invasion experienced problems with acquiring GPS signal and it was not possible to test them in action. Zombies, Run! is based on audio input and is available only in English, therefore it was not suitable for some of the participants who do not have a good command of English language. As a result, there were three games left for consideration – Temple Treasure, Ingress and SpecTrek.

Temple Treasure appeared to be very trivial, besides periodically it experienced problems with connecting to location services, and GPS positioning did not seem to be accurate, which caused confusions while trying to locate the Guardians. Moreover, the map was confusing as well, as it only showed the locations of player and Guardians and a trail between them. There was no compass to determine the right orientation, and the Google map's street view was overlaid with a solid background, showing only street names, which was confusing.

Ingress, on the contrary, has very neat design and convenient navigation system, but at the same time, it is quite complex for beginners and, assuming that most of the participants are not familiar with this game or any MAR game in general, it would require a considerable amount of time to teach them the rules and basics of the game. In addition to that, unlike two other games, Ingress does not have any time limits, so it provides quite a relaxed gameplay, where player can simply stroll along the streets, enjoying the walk and discovering new Portals along the way. Without a doubt, it is a good motivator for going outside and walking for hours, and as a result can also contribute to the active lifestyle.

SpecTrek happened to be the "golden middle" of the three games. It is not too simplistic like Temple Treasure, but also not as complex as Ingress, it does not require any tutorials or long explanations for the gameplay and interface. The navigation system is clear as well, and GPS positioning works quite precisely. Having time limit for each ghost hunt is expected to force the participants to move more actively while playing the game, hence making more steps within a shorter period of time.

Thus, after the preliminary testing of each of the three selected MAR games and considering all pros and cons, SpecTrek has been chosen as the testing game for the case study.

2.2. Participants

Ten young people in the age group of 15-29 years old (M=23,4; SD=4,65) have been selected for this study. Adolescents and young adults tend to spend more of their free time in front of computer (including playing games), limiting their physical activity. Such behaviour may provoke serious health issues in an older age, thus preventive action must be taken in a younger age. Additionally, according to ExactTarget (2014) people from this age group are the most active smartphones users, and playing mobile games takes quite a big part (about 57%). At the same time it was not intended to involve only dedicated gamers or only physically inactive participants, because it is important to see and understand how mobile exergaming is perceived by young people with different lifestyles. Thus, participants in this case study are so diverse.

A summarized self-reported data regarding participants' background is introduced in Table 2. Levels of PA were determined with a General Practice Physical Activity Questionnaire (GPPAQ), a quick and simple tool for subjective assessment of PA among adults (aged 16-74) on a 4 level scale (inactive, moderately inactive, moderately active and active) (PA Policy, 2009). This data was needed to assess how participants with different levels of PA

perceive the physical load during exergaming and also find out whether it is related with their previous gaming experience (i.e. participants who play games more often are less active).

Two of the participants are school students aged 15 and 16, they spend up to 7 hours in school from Monday to Friday, and most of this time, excluding gym classes twice a week, is spent sitting in classrooms. Out-of-school time is also spent mostly in sedentary positions – doing homework, watching TV, browsing Internet or playing computer games. One of the teenagers admitted that often, especially on the weekends, he plays his favourite video game for several hours without a break.

Four participants are university students between 21-26 years old, and they spend big amount of time sitting as well – in classes and at home, working on assignments or engaging in sedentary leisure activities. Only one of them attends gym for 2 hours three times a week, increasing amount of PA in his life to some extent.

Finally, four other participants are young adults between 25-29 years old, having sedentary jobs at offices. One of them is concerned about her extra weight and links this problem to the lack of PA in her life, but at the same time, she claims that she gets very tired at work, and so she has neither energy nor desire for exercising. Another participant confessed that he had previously tried to make workouts a habit, but soon he gave up because of losing motivation.

Table 2. Participants' Background Data.

	Age	**Playing Experience**	**Frequency of Playing**	**Physical Activity**
P1	26	AR-game(s); mobile	occasionally	moderately inactive
P2	26	console	weekly/few times a week	active
P3	29	console	weekly/few times a week	active
P4	25	mobile; console	occasionally	active
P5	25	-	-	moderately inactive
P6	24	mobile; console	weekly/few times a week	active
P7	21	mobile	daily	moderately active
P8	27	-	-	moderately inactive
P9	15	mobile; console; PC	daily	moderately inactive
P10	16	mobile; PC	occasionally	moderately active

All of the participants have played computer or video games in their lives, but just three of them play on a daily basis. Six play mobile games occasionally, mostly to kill time in public transport or while waiting in lines. Two participants had not played any games in the last 3 years, so their playing experience was marked as absent.

Experience with a MAR game was new for the majority of the participants, because only three of them were familiar with the concept of AR and had heard about games based on this technology. One participant had even previously played a MAR game, namely Ingress, so she also had a chance to compare the two games.

2.3. Data Collection Instruments

In order to assess SpecTrek both from PA and UX perspectives, different tools have been used during and after the testing for collecting both qualitative and quantitative data.

Pedometer

According to Tudor-Locke & Myers (2001), pedometer is the simplest objective instrument for measuring PA and it is especially useful in capturing walking behavior. Since walking is the key activity in SpecTrek gameplay, pedometer is employed for counting the amount of steps taken by the participants.

Map Tracking

In addition to measuring steps, the participants' locomotion was also tracked, using a mobile application "Map My Tracks", a fitness app that tracks and records user's walking, running or driving trails on the map, as well as the distance travelled, speed, pace and elevation (Figure 14). Map tracking will be used mainly for analysing the patterns of the participants' movement while playing the game, but also to see how many kilometres they walked.

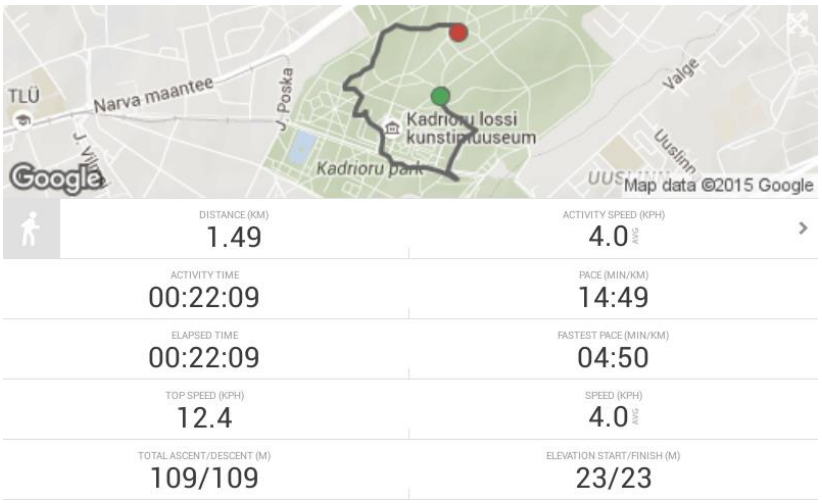

Figure 14. An example of "Map My Track" Mobile App tracking statistics.

Contextual Inquiry

Apart from measuring physiological indices, it was important to assess the emotional side as well, because active MAR games should not only provide fitness opportunities, but also deliver good and pleasant UX, urging the users to play the game repeatedly. Therefore, observation along with contextual interview (i.e. during the game testing) were applied to see and understand how the participants interact with the game, what they think and how they feel. Voice recording in the context of outdoor environment with a high level of background noise (e.g. transport, footsteps, wind) was problematic, so written notes were taken instead.

Game Experience Questionnaire

In order to perform a more in-depth evaluation of UX provided by SpecTrek, participants were also asked to fill in the Game Experience Questionnaire (GEQ), developed and validated by researchers at Eindhoven University of Technology (IJsselsteijn et al., 2008).

GEQ is applied after playing a game, and can be applied several times over a longer period in order to track the changes in experience. It is suitable both for field and lab studies, and can be used for any type of digital game. The questionnaire consists of a list of statements mostly concerning user's feelings and uses Lickert scale (from 0 to 4) for each statement.

There are three basic modules in GEQ:

1. **Core Module** - concerns actual experiences during game play. It assesses the game experience according to seven key elements: Immersion, Flow, Competence, Positive and Negative Affect, Tension and Challenge.
2. **Social Presence Module** - concerns gaming with others. It investigates Psychological and Behavioural Involvement with other social subjects, either virtual (e.g. in-game NPCs (Non-Player Characters)), mediated (e.g. other players playing online, for example in MMORPGs (Massively Multiplayer Online Role-Playing Games)) or co-located (e.g. friends playing together multiplayer video game on console). This module should only be included in case at least one of those types is involved in the game, therefore it was excluded in this case study.
3. **Post-Game Module** - concerns experiences once a player has stopped gaming, i.e. how players felt after they had stopped playing a game. It evaluates Positive and Negative Experience, Tiredness and Returning to Reality.

The list of all the Core Module and Post-Game Module items can be found in the Appendix.

The authors consider flow one of the important characteristics that needs to be measured in a gameplay. The "father" of the concept of flow, Csikszentmihalyi (1990), defined it as "a state of concentration so focused that it amounts to absolute absorption in an activity." IJsselsteijn, de Kort & Poels **(**2007) add that flow can also be defined as "a state of balance between challenge and skill", and such definition can be applied very well in the sense of playing games. When the challenge is so great that it becomes above player's skills it causes frustration. On the other hand, if the challenge is too little, it may soon make the game boring. Thus, it is evident that challenge provided by a game influences motivation, an important factor that makes players to continue playing the game and return to it on a regular basis. Jackson & Csikszentmihalyi (1999) also state that in order to maintain the interest of a participant (or a player in case of games) skills need to be matched with challenges, it is called "the golden rule of flow". Since GEQ measures both competence (that can be also interpreted as skills) and challenge, it will be helpful in determining whether the game is motivating enough.

Another characteristic accentuated by IJsselsteijn et al. is immersion. While some scholars consider it equivalent to flow, it is different in terms of games. Sweetser & Wyeth (2005) even proposed a modified model of Csikszentmihalyi's Flow and called it "Gameflow". Their Gameflow model consists of eight components: Concentration, Challenge, Player skills, Control, Clear goals, Feedback, Immersion and Social Interaction. Thus, Immersion, in their opinion, is merely one of the components of Flow (and Gameflow), but not equal to it. They define it as "deep but effortless involvement in the game." In psychology this notion has been termed as "presence", and what gamers think of as immersion is "spatial presence" (Madigan, 2010), but essentially it is all the same and means the sense of belonging and existing within the world created by the media, be it a book, a movie or a game.

To further define immersion, we can say that, first of all, it is engagement with the story, narrative and the game world, and often it affects imagination, whereas flow is concentration on the game mechanics and task performance. What makes these two characteristics so similar is that both can have the same effect on the player, e.g. loss of self-consciousness (player is no longer self-aware and/or is identified with the game character or avatar) or transformation of time (player loses track of time). Moreover, immersion in games is also determined by realism of the game world (e.g. natural behaviour of NPCs, realistic interaction with the objects, open game world). Usually puzzle or arcade games like Tetris, Minesweeper or Donkey Kong do not have any narrative or rich game world, but they still

engage players by creating flow instead. Adventure and RPG games (e.g. Assassin's Creed, Fable, Red Dead Redemption), on the contrary, usually immerse players with their bright, fantastic game worlds and interactive story. Although often such games combine both flow and immersion.

Lastly, another element of GEQ worth mentioning is Tiredness and usually it concerns emotional tiredness after the game, but in case of exergaming it could also involve physical tiredness, therefore this key element of Post-Game Module will also be of a particular interest in this case study.

2.4. Implementation

Participants were tested separately, one at a time, on a specified date, suitable for the participant, during one week. The testing took place in the Kadriorg Park due to its vast open area, where players can walk freely, and the locomotion is not hindered by the obstacles such as roads with intensive traffic. Moreover, it also ensures the safety of the players, as they may immerse in the game too much and stop paying attention at the surroundings, as a result, getting exposed to various threats, e.g. driving cars.

Before starting the testing session, each participant was familiarized with SpecTrek, its interface, mechanics and main rules. The pedometer was attached close to the participant's body to ensure more precise step detection. The "Map My Track" app works on the background, so it was launched along with the game at the beginning of the game session and stopped in the end.

The game's default Medium mode (45 minutes) was selected for the tests, as it is the most optimal option. Short mode does not provide enough experience, while Long mode can be too much time-consuming. All participants had the same starting point, although the game randomly generated ghosts' locations for each player, which resulted in diverse game progressions. During the testing sessions, participants were asked to freely express their thoughts, feelings and opinions about the game. The most significant remarks were noted down by moderator who followed the participants on their "ghost hunting" paths. Moderator was merely observing the participants and was not allowed to interfere or help them in any way.

After finishing the game, regardless of the results, all relevant data (i.e. amount of time required to complete the quest and amount of steps) has been noted down for further analysis. Participants were asked to share their general impression of the game and fill in GEQ. The

questionnaire was applied via Google Forms, as it is a simple tool that records and stores all responses in a table (i.e. Google Sheets) that can be downloaded as an Excel file. It also provides a convenient graphical summary of responses (in forms of graphs) for a quick overview.

2.5. Analysis

In order to analyse all the gathered data, it was unified in one database, separately for each participant. Although the number of participants is too low to make statistical correlations, it is still possible to apply pattern matching technique, where an empirically based pattern is compared with certain predictions. Yin (2013) suggested this method for qualitative analysis in case studies. First of all, it was necessary to find out if the hypothesis about frequent game playing decreasing physical activity in players was true for the selected group of participants. This could be revealed through the self-reported data about participants' lifestyle and gaming experience.

Next, this self-reported background data was also merged with the game test results (i.e. amount of steps and kilometres, completion time and result) and compared to find any meaningful patterns in participants' behaviour. For example, how fast participants with different previous gaming experience reach the game's goals and whether it depends on their overall physical fitness. The means of game test results were also calculated to assess the average level of PA provided within the taken playing time.

Before scoring the key elements of GEQ and obtaining evaluation results, it was necessary to separate responses according to the scoring guidance provided by JIsselsteijn et al. in their official document. Each of the items in the questionnaire corresponds to a particular component (Table 3) and provides 0 to 4 points. The final value of each component is the average value of all of its respective items. GEQ results proved useful not only for evaluating general user experience, but also for further analysis of participants' behaviour and their attitude towards the game. Once again, previous gaming experience appeared to be an important differentiating factor.

Furthermore, content analysis of observation and contextual interview notes provided more empirical data and added to the theoretical base. It also helped to build explanations for certain patterns. Thematic coding was used to identify common positive and negative remarks about the game and gameplay, important for determining possible advantages and disadvantages, as well as what can be done in order to increase user motivation to play mobile exergames.

Finally, all the gathered evidence and the most important and relevant findings were also linked to the related studies both on static and mobile exergaming, described in chapters 1.3 and 1.7 respectively. And although it was impossible to generalize the findings of the present study to the wider population, some generalization could be done through previous research and theoretical background.

Table 3. Statements related to GEQ components in the Core and Post-Game Modules.

<table>
<tr><th colspan="2">Core Module</th></tr>
<tr><td>Competence</td><td>Tension/Annoyance</td></tr>
<tr><td>(2) I felt skillful
(10) I felt competent
(15) I was good at it
(17) I felt successful
(21) I was fast at reaching the game's targets</td><td>(22) I felt annoyed
(24) I felt irritable
(29) I felt frustrated</td></tr>
<tr><td>Sensory & Imaginative Immersion</td><td>Challenge</td></tr>
<tr><td>(3) I was interested in the game's story
(12) It was aesthetically pleasing
(18) I felt imaginative
(19) I felt that I could explore things
(27) I found it impressive
(30) It felt like a rich experience</td><td>(11) I thought it was hard
(23) I felt pressured
(26) I felt challenged
(32) I felt time pressure
(33) I had to put a lot of effort into it</td></tr>
<tr><td>Flow</td><td>Negative Affect</td></tr>
<tr><td>(5) I was fully occupied with the game
(13) I forgot everything around me
(25) I lost track of time
(28) I was deeply concentrated in the game
(31) I lost connection with the outside world</td><td>(7) It gave me a bad mood
(8) I thought about other things
(9) I found it tiresome
(16) I felt bored</td></tr>
<tr><td></td><td>Positive Affect</td></tr>
<tr><td></td><td>(1) I felt content
(4) I thought it was fun
(6) I felt happy
(14) I felt good
(20) I enjoyed it</td></tr>
<tr><th colspan="2">Post-Game Module</th></tr>
<tr><td>Positive Experience</td><td>Negative Experience</td></tr>
<tr><td>(1) I felt revived
(5) It felt like a victory
(7) I felt energized
(8) I felt satisfied
(12) I felt powerful
(16) I felt proud</td><td>(2) I felt bad
(4) I felt guilty
(6) I found it a waste of time
(11) I felt that I could have done more useful things
(14) I felt regret
(15) I felt ashamed</td></tr>
<tr><td>Tiredness</td><td>Return to Reality</td></tr>
<tr><td>(10) I felt exhausted
(13) I felt weary</td><td>(3) I found it hard to get back to reality
(9) I felt disoriented
(17) I had a sense that I had returned from a journey</td></tr>
</table>

2.6. Validity and Reliability

Ensuring validity and reliability of data, necessary for a rigorous research, becomes challenging in case study due to its constructivist nature. Riege (2003) considered this issue and developed a scientific framework of tests and techniques for validity and reliability in case study research, and his framework was also used in this study. Reliability and at least one type of validity on each stage of the research are summed up in Table 4.

Table 4. Validity and Reliability on different research stages.

	Construct validity	Internal validity	External validity	Reliability
Research design	Clearly defined research questions and goals	Researcher's assumptions, worldview, theoretical orientation		Full account of theories and ideas
Data collection	Multiple sources of evidence (including previous studies)	Triangulation (use of different data collection instruments, both qualitative and quantitative)		Meticulous note recording during observation; Case study database
Data analysis		Pattern matching; explanation building	Comparing evidence with existing literature	Full account of theories and ideas
Report writing	Participants' review of draft case study report			Peer review (by supervisors)

When planning the research the author made a review of existing literature in the corresponding area to understand the current state of art as well as actual problems and how they are being dealt with. This also helped in defining research goals and questions for current study and search for answers and solutions.

Multimethodology, i.e. use of different data collection methods, allowed to gather various types of data, both qualitative (interviews, observations) and quantitative (questionnaire, pedometer). Full summary of all data collected during the case study can be found in

appendices in the end of this document. To reach external validity, findings from the related studies were taken into account and used to make generalizations where possible, since the sample of the current case study is not enough to generalize the findings.

While writing the report the author communicated with some of the participants in order to clarify or define more exactly certain parts of the interviews, or add missing data. The draft case study report was introduced to two of the participants as well as supervisors in order to make changes and improvements and suppress the author's biases.

3. Results

Overall, all participants were more positive than negative about the game, even though 3 of 10 failed to actually complete the game in due time. The failure was mainly caused by lack of orientating skills, as these three participants got confused with following the map and had hard time understanding where they are at the moment and where they should go, eventually running out of time. This was also visible on the map, compared to a participant who did not have much problem with orientating (Figure 15).

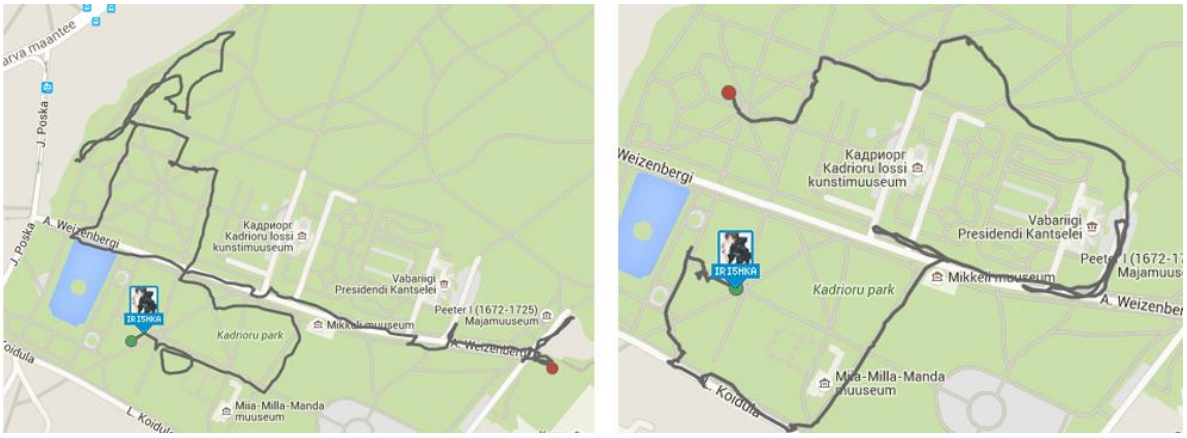

Figure 15. Examples of participants' map tracking. Participant 5 (left) was extremely confused with the map and roamed around ending up losing the game; Participant 4 (right) felt more confident with the map, clearing ghosts one by one and finishing the game fast.

It was particularly interesting to find out that the participants, who had the best results and the least problems with following the map, have previously played map-based computer and video games. For example, when Participant 4 was asked whether he found it hard to orientate himself in the real world environment according to the game map, his response was: "Not at all, it's just like in GTA[1]!" This previous gaming experience might have made it easier for him to navigate while playing SpecTrek. At the same time, both participants who did not play any games in the last 3 years (i.e. had the least gaming experience) failed to complete the game in time.

Another participant, who got confused with the map, said that this game would be very useful in teaching her how to read maps and use compass. Several participants also noted that it would be interesting to play this game in an unfamiliar location, as it helps to explore the

[1] Grand Theft Auto (GTA) – popular video games series with huge in-game world maps, requiring players to navigate through them.

area in a fun and playful way and, for example, learn the street names and other local places of interest.

3.1. Physical Activity and Load

Preliminary analysis of participants' levels of physical activity and gaming experience gave unexpected results. It was hypothesized that playing games more often had decreased amount of PA in participants' lives, but it was not confirmed. Moreover, participants who spent more time playing games were also more physically active comparing to the participants who played rarely or did not play at all. However, physical fitness was a self-reported variable measured by a short and simple questionnaire, so it is not fully objective.

Table 5 shows the summary of all data required to measure the amount of physical load provided by the game. In case of failure the completion time is indicated as 45 minutes (the limit of the game session), because essentially this was the amount of time the "failing" participants spent playing.

It is worth noting that any result was being accepted, and winning the game was not required. Besides, this is the case when the famous saying "*It is not whether you win or lose, it is how you play the game*" found its new meaning. Participants who failed, had to spend more time playing than the participants who managed to win the game and finish before the time ran out. This means they walked longer distances (this can also be seen in the Table 5) and, as a rule, received more physical load, which was the main intention and purpose of the game.

Table 5. Game completion results for each participant.

	Steps taken	**Completion time**	**Km walked**	**Result**
P1	2124	0:33:34	1,88	**Completed**
P2	1822	0:22:10	1,49	**Completed**
P3	1969	0:28:03	1,57	**Completed**
P4	3225	0:32:14	2,01	**Completed**
P5	2246	0:45:00	2,71	**Failed**
P6	2768	0:34:12	2,29	**Completed**
P7	1870	0:21:05	1,52	**Completed**
P8	2157	0:45:00	2,56	**Failed**
P9	2017	0:31:46	1,79	**Completed**
P10	2987	0:45:00	2,62	**Failed**
AVG	**2318,5 (≈2319)**	**0:33:48 (≈34 min)**	**2,044 (≈2 km)**	

Calculating the average results showed that, in general, playing SpecTrek, one can walk around 2 km in 34 minutes, making 2319 steps. That provides basal physical activity according to Tudor-Locke & Bassett (2004) table. In order to reach recommended activity level (i.e. 10 000 steps per day) we can assume that one needs to play this game at least 2 hours.

3.2. Discovered Drawbacks and Limitations

Some considerable drawbacks and limitations to the game were discovered during the tests. They were divided in two categories: objective, that are not directly related to the game itself, but are more dependent on outside factors; and subjective, mostly related to the gameplay and provided user experience.

Objective Limitations

- It does not run, takes too much time to start, or works with glitches on some devices. This was true mostly for older versions, e.g. the game could not be started on two different Sony Xperia phones (Go and Z1) and experienced accelerometer and AR positioning issues on Toshiba Excite tablet (ghosts appeared in horizontal position (Figure 16)), which caused difficulties for catching ghosts.

Figure 16. Position glitch in Toshiba tablet.

- Takes up a considerable amount of system resources (mainly due to enabling GPS and Wi-Fi for better and faster locating results) and drains device's battery in quite a short period. The device has to be fully charged before starting the game to ensure prolonged playing, required for better physical activity involvement.
- Environment limitations and physical obstacles. Although the testing took place in a relatively traffic-free area, still few times participants were in danger of being hit by

a car, because they were too much concentrated on the game and stopped paying attention at what happens around them. One participant also accidentally stepped in a puddle once. Sometimes ghosts appeared to be found in unreachable locations, but fortunately developers thought of adding a function to scare the ghost away by blowing a virtual horn, which makes an unreachable ghost flee to another location.

- Weather limitations. There must be a certain weather condition too, in order to ensure a more comfortable playing. It is best to play when it is cloudy, because on a very sunny day the phone/tablet screen is murky and hardly visible. Increasing brightness can solve this, but at the same time, it contributes to faster battery drain. Needless to say, cold, rainy and/or windy weather impedes playing as well.

Subjective Limitations

- Not enough motivation. Five participants noted that this game was not likely to motivate them to go out and engage in a physical activity often, because it would become boring soon.
- Lack of variety. This was one major reason why the game has a potential to bore players quickly. Participants suggested adding more challenges, like quests or missions, that would impact leveling up and unlocking new features. Another suggestion was to add more ghost types or ability to collect ghosts similar to Pokemon. This would give some motivation to keep on playing the game as often as possible.
- Lack of social module. Participants would also like to have an opportunity to connect the game to their social networks accounts, share their in-game progression and compete or collaborate with their friends.
- One participant admitted that she feels uncomfortable playing this game alone, as she thinks that people look oddly at her while she is walking around with her phone in hands, spinning and tilting it in all directions and pointing at something. Although playing together with friends by her side would not feel so weird, besides they can watch her step and prevent from getting into accidents.

Positive Remarks

Despite of all the criticism, participants have also found some good sides of the game. As it has been mentioned before, one participant said that this game is useful for teaching orientating. Another participant speculated that this game could be a good outdoor activity to do with kids, for example while going on a picnic or on vacation somewhere in rural area.

In general, all of the participants admitted that they had a new and interesting experience playing SpecTrek and would consider playing this or similar game if it met their expectations described in the list of subjective limitations.

3.3. GEQ Results

Finally, GEQ would give a more objective representation of received user experience. Core module consists of seven components: competence, sensory and imaginative immersion, flow, tension/annoyance, challenge, negative affect and positive affect (Figure 17). Post-Game module includes four components: positive and negative experience, tiredness and returning to reality (Figure 18).

The maximum value of each component is 4, but the game did not reach this number in any of the categories. Overall, it got medium results for most of the categories, with 2,64 points for positive affect during the game and 2,12 for positive experience upon finishing the game. As for negative affect and experience, they were minimal - 0,83 and 0,25 points respectively.

At the same time, the game was not very much challenging (1,5 points), which was also confirmed by the participants as they were thinking out loud during the gameplay and sharing their opinion on the game afterwards. There is also enough room for improvement in terms of competence, immersion and flow. Since all those elements influence players' motivation to play, such middling indices explain why half of the participants called the game not very much motivating.

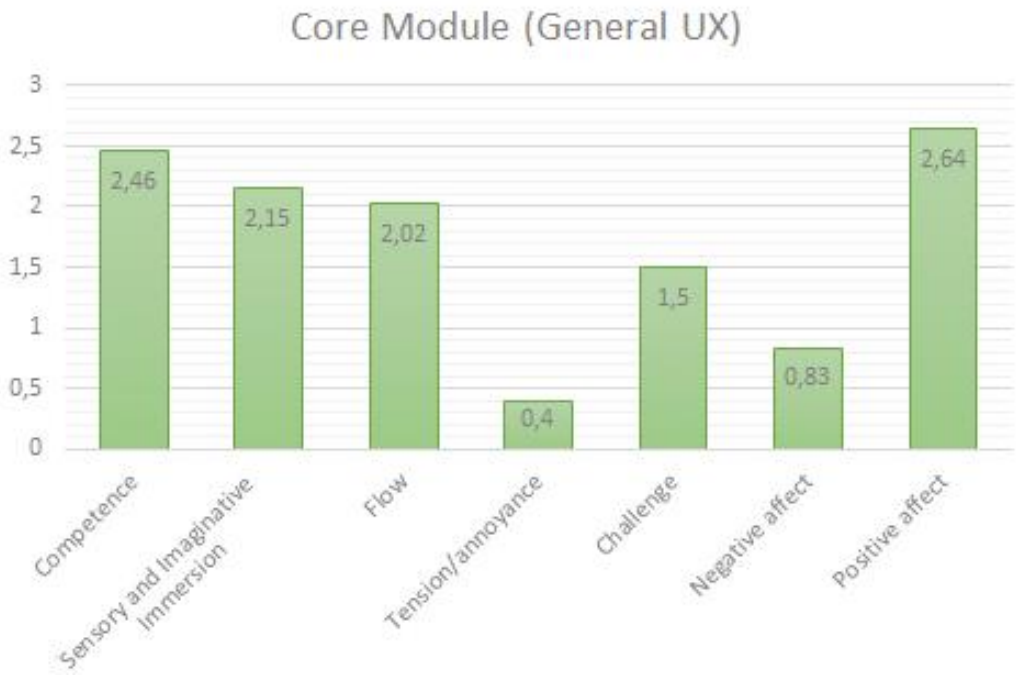

Figure 17. Core Module results.

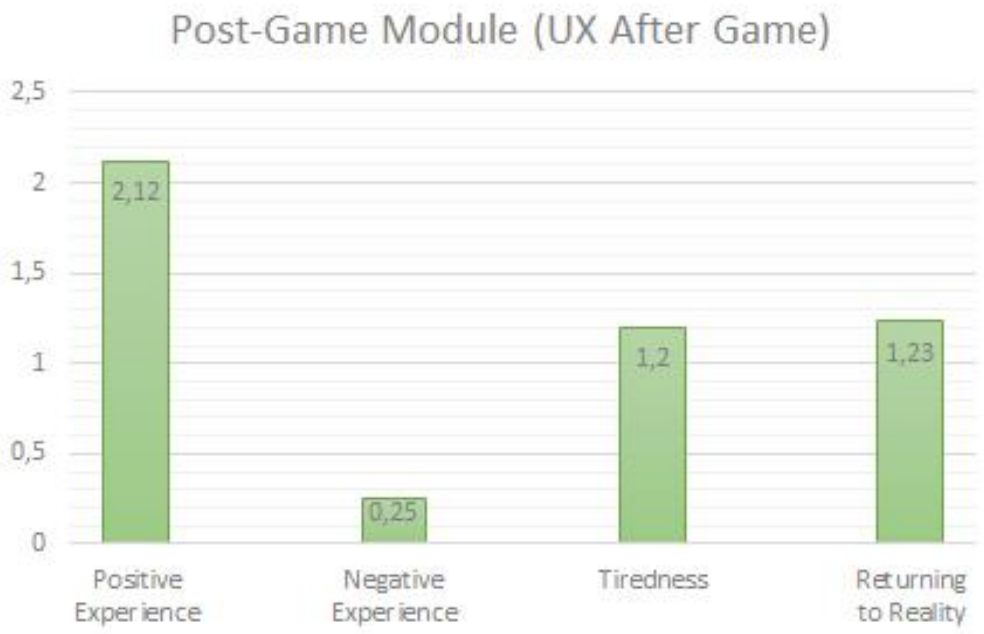

Figure 18. Post-Game Module results.

Tiredness level in the Post-Game module is quite low (1,2 points), indicating that the game was not exhausting for the participants and did not take much of their physical strength. Perhaps it can be due to the short duration of the game session and reasonably low physical load. The participants did not play long enough to start feeling emotional and physical weariness. Pearson correlation analysis revealed weak correlation (r=0,364) between participants' pre-determined level of PA and Post-Game Tiredness, meaning that less active participants tended to become more tired during the game than active participants. At the same time, those participants either failed to finish the game or it took them longer than others, thus it may be the true reason why they felt more tired than more successful participants - they simply had to play longer.

Returning to Reality value indicates how hard it was for players to switch from the game back to the real world. It was quite low for SpecTrek (1,23 points), which means players switched back to reality quite easily. This can be partly explained by the fact that AR game does not create fully virtual gaming world, but merely incorporates some virtual gaming elements into the real world, so players were mostly aware of the surrounding reality, because they had to move through it to achieve the game tasks and goals.

Additionally, analysis of participants' background information (i.e. age and gaming experience) was made in order to attempt finding any dependence on motivation. Four elements (Competence, Immersion, Flow and Challenge) from the Core Module were taken as main indicators (Table 6).

Table 6. Comparison of Competence, Challenge, Immersion and Flow depending on participants' age and gaming experience.

	Age	Mean
Competence	>= 22	2,54
	< 22	2,27
Challenge	>= 22	1,51
	< 22	1,47
Immersion	>= 22	2,20
	< 22	2,00
Flow	>= 22	2,06
	< 22	1,93

	Gaming Exp.	Mean
Competence	>= 2*	2,60
	< 2**	1,90
Challenge	>= 2*	1,20
	< 2**	2,70
Immersion	>= 2*	1,96
	< 2**	2,85
Flow	>= 2*	1,80
	< 2**	2,90

** occasionally, weekly, daily*

*** never, rarely*

All of the elements' means are slightly higher in the older participants, however Independent Samples T-Test showed that this difference is not significant in either cases, so the participants' age is not likely to have an impact neither on how they perceive the game nor their motivation.

Previous gaming experience, on the other hand, yielded quite diverse results between the participants who have no or very little gaming experience and those who play more often or on a regular basis. Thus, more experienced players felt more competent while playing and most likely this was also the reason they felt less challenged than non-experienced participants. Their skills outmatched the challenge provided by the game and it became boring. Relatively low means of Flow and Immersion also add up to that assumption. However, once again there is no significant difference between the means. The only exception is Challenge ($p<0,01$), which indicates that less experienced participants felt more challenged than the participants with bigger experience, and this difference is significant.

To sum up, the tested MAR game was able to generate basal PA in its players during up to 45 minutes playing session and received mostly positive feedback, but the general user experience that it provided is unlikely to attract the players and motivate them for continuous use.

4. Discussion

The theoretical information and practical data gathered throughout this thesis helped in finding answers for the three main research questions stated in Introduction. They will be discussed one by one further in this chapter.

4.1. Advantages and Disadvantages of MAR games

Mobile AR games have several advantages as compared to computer games and even console-based exergames. First of all, they are pervasive, as nowadays a big majority of the population owns smartphones, while not everyone has a gaming console or powerful PC for playing games. Secondly, mobile games are more affordable, moreover, many of them are free to download and use. AR content makes such games novel and opens new opportunities for a completely non-typical gameplay. Mobility of smartphones allows users to play outdoors and engage in a more natural physical activity, as most of the known and existing MAR games rely on so-called movement-based interaction, where users are required to walk in order to reach game goals. Walking is one of the easiest yet effective types of PA accessible for everyone regardless their initial physical state and background. All of these advantages show that MAR games could have a great potential in facilitating PA in their players.

However, there are few considerable downsides of such games, too. Mobile devices are constantly advancing and improving, so perhaps some of those drawbacks will be successfully eliminated in future, but so far fast battery drain and GPS positioning problems are among the most experienced technical problems. Continuous play with a switched-on screen and active GPS tend to consume battery power in short term. Some developers saw to that issue and made their games able to run in the background, with a switched-off screen, and providing users with audio signals and notifications when necessary. Such approach could also help in solving another issue with MAR games that are meant for playing in outdoor environment.

Urban environment that often serves as the main playground for many MAR games is full of potential threats for their users e.g. traffic, pits and open manholes, various obstacles on the way. When players become too concentrated with the game while looking at their smartphone screens, they may become unaware of the surroundings and accidentally hurt themselves. Many researchers in the field of mobile and context-sensitive gaming have also

highlighted the need to ensure users' safety while moving around the city with their attention focused on their smartphone screens (Boyd Davis, et al., 2007). Dutz et al. (2014) state that mobile active games that rely on user's movements should be adaptive and balance the complexity of interaction with the game and the intensity of movement that it requires. If the user is required to concentrate on the road, the game should not demand too much attention and ask her to focus on the screen, but instead it can provide audio feedback. If there is not much physical activity involved at the moment, then the game's interface can change its complexity and capture user's attention.

These nuances can make design and development of such games quite challenging. Knöll and his colleagues (2013) even proposed a multi-disciplinary approach. They suggest that while computer scientists are responsible for development and programming of the game, psychologists, architects and urban designers should also be involved in the process. Urban design must provide suitable and comfortable game context and possibly adding up to the game story and increasing immersion, and both psychological and physiological effects of the game should be assessed properly. However, such method happened to have its own downsides - difficulties in inter-disciplinary communication and limitations in use of the designed games (some games were designed to play in a specific park or other urban area in a certain town).

Moreover, playing outdoors in public places with many people around may be uneasy for some shy gamers, like it happened in this case study with one of the participants, who claimed that she felt embarrassed while running around with a phone and pointing it at different spots trying to catch virtual ghosts. She thought that people looked at her with surprise and curiosity, and she did not like that kind of attention from strangers. Garn et al. (2012) point out that some people may experience social anxiety associated with public physical activities. That is why ability to exercise in the comfort of their own homes is more suitable for socially anxious people. Static exergames give them such opportunity, therefore they may be more preferable than mobile exergames, although finding more secluded areas outdoors can be a solution as well. On the other hand, Gehl (2012) states that seeing and hearing other people in a public space makes us feel safe, and especially that concerns children, who prefer to play in populated places.

Additionally, the outdoor nature of MAR games makes them dependent on the weather. It is unlikely that the gamers will want to go out to play such games in rainy or cold weather,

especially in winter, thus the opportunities for mobile exergaming outdoors will be limited, and this is another case where static exergames outstrip their mobile counterparts.

4.2. Physical Activity Facilitation

Despite their novelty, MAR games are not pioneers in terms of gamification of physical exercising. Exergaming as a concept has existed since the late 80's, but scientific studies addressing their effectiveness began to emerge only in the 21st century. Various case studies and experiments were performed with different games and on different groups of participants, both young and old. Most of them showed that indeed active video games can be a good source of PA, especially for children, and can be considered an effective way of exercising, however they cannot fully substitute real fitness or gym training, as the levels of physical exertion are lower during exergaming. On the other hand, gamification factor proves out and makes exergaming more fun and entertaining than usual exercising.

At the moment, MAR games are not studied as thorough as static exergames, although many researchers and scholars had shown interest in this topic, few focus on measuring PA. The main intention of the case study within this thesis was to determine whether a chosen MAR game is able to provide physical activity to its players and to what extent. Pedometer results showed that indeed players get a basal level of physical activity during one average game session (i.e. Medium 45-minutes game mode completed in 30 or more minutes), however this is not enough for a healthy lifestyle. These findings generally conform to previous studies by other researchers. Austin et al. (2010) and Chittaro & Sioni (2012) also discovered that their game prototypes did not sufficiently increase PA in their participants during the tests, but they assume that playing for a longer time and on a regular basis may have more effect. Similarly we can expect that in order to reach a high activity level, recommended by Tudor-Locke & Basset, players have to spend at least 2 hours playing SpecTrek.

Since it may be difficult for some people to play the game for 2 hours, it is possible to combine it with other physical activities. For example, one can simply go for a walk in the park for an hour, and then play the game for another hour. It is also possible to play with a friend or several friends and take turns, i.e. one friend plays a session, other friend(s) follow and then they switch places and so on. This way, people who follow the player receive similar physical load and, in the end, everyone can reach equal activity level.

It is also important to notice that despite all the differences between static and mobile exergames, and advantages and disadvantages of both parties, neither can compare in

effectiveness with actual exercising, but they are still better than traditional sedentary games, because they facilitate PA to some extent. Ideally, exercising and exergaming (both static and mobile) could be combined interchangeably, and for example, one can go on jogging or do physical exercises in a gym 3 times a week and on other days play exergames on console at home, or go outside and play active MAR games if the weather allows.

Another aspect of exergames with a positive impact on players is that such games can make them aware of their fitness e.g. by tracking calories, and as a result players become more concerned about their health and receive more motivation to proceed exercising in the future.

4.3. Motivating Triggers

In order to stimulate users to exercise and keep in shape, MAR games should be motivating and attractive per se. No matter how effective the game is in providing PA, if it is boring or not engaging enough, it will fail in accomplishing its true mission. In all previous studies (e.g. Lindeman et al., 2012; Chittaro & Sioni, 2012) as well as in the case study within this thesis, all participants who tested the MAR games expressed great interest in AR content and liked the idea of combining mobile games with physical exercising. Such attitude was caused mainly by the novelty factor, but it works only on the initial stage for attracting new users. Later novelty loses its power with repeated and frequent use (Kosoris & Chastine, 2015). Since active MAR games are meant to be used frequently in order to achieve health benefits, relying merely on innovative AR content is not enough for engaging users in a long-term perspective.

In her Master's thesis, Monk (2014) derives four mobile exergaming heuristics aimed at determining motivational and engagement factors that should be taken into account for designing and developing successful and efficient mobile exergames. Essentially, exergames must immerse players with plot and story, match players' fitness levels, have an encouraging reward system, and provide audio and haptic (i.e. through vibration) feedback when the player is not required to focus on the screen. Furthermore, some researchers also consider social interaction, be it virtual, mediated or co-located, an important motivational element (Nijholt, van Dijk & Reidsma, 2008; Kosoris & Chastine, 2015).

In case of SpecTrek, user experience evaluation showed that the game provides little challenge to its players; and levels of competence, immersion and flow are not enough to ensure engagement with the game and motivate people to keep on playing it in the future. This was confirmed by most of the participants, who claimed that although the game seems

interesting and fun to play, it would not really persuade them go out and play on a regular basis and make it a habit. Although the case of "Walk with me" game revealed that not all people welcome challenge and would like to have an opportunity to select between different game modes - with and without challenge (Tamm, 2014). Additionally, SpecTrek case study participants noted that they would like to have opportunity to create and connect their game accounts with social networks and share and compare their results with other players and friends who play this game as well. This corresponds to other researchers' notions about the importance of social interaction in games.

As it has been argued earlier, Flow is one of the significant components in game experience, also responsible for inducing motivation, and Flow in games is slightly different from Csikszentmihalyi's original Flow concept. When it comes to exergames, assessing Flow on the gameplay level is not sufficient, as exergaming combines both gaming and exercise. Therefore, Sinclair, Hingston & Masek (2007) proposed a Dual Flow model for exergames, where flow in gameplay (psychological) and flow in exercise (physiological) are presented as two separate dimensions – attractiveness and effectiveness (Figure 19). If the gameplay is able to create flow, the game will be attractive for the players, otherwise they will become anxious (if the game is too challenging) or bored (if it does not match their skills) and/or completely lose interest. Similarly, if physical load provided by the exergame is too great and is above player's capabilities, they will fail; if intensity is too low, it will have no effect on the player, and, as a result, there will not be any health benefit either way.

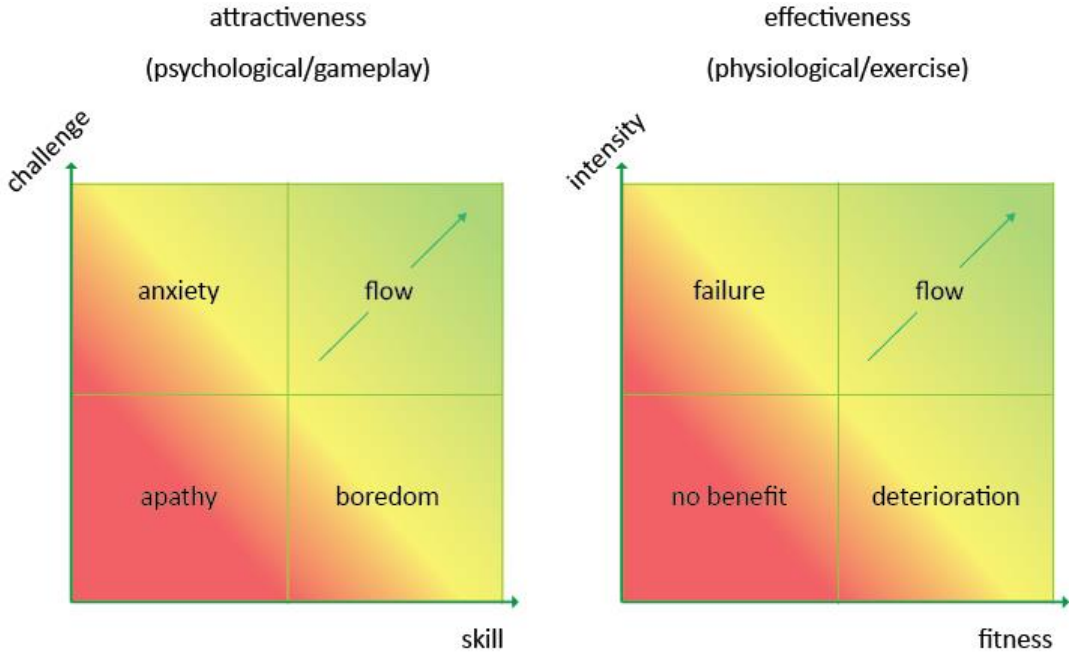

Figure 19. Dual Flow © Sinclair, Hingston & Masek (2007).

Both psychological attractiveness and physiological effectiveness are important for motivation, and although the authors suggested this model for standard (i.e. static, console-based) exergames, the same prerequisites should be applied in designing mobile exergames, too.

Some studies showed that the fitness and physical state of the players may also influence their motivation. Chittaro & Sioni (2012) in particular found out that participants who led more sedentary lifestyle enjoyed physical exercising while playing an active mobile game, whereas more active participants claimed they could not fully enjoy exercising because they were too concentrated on the game, so usual walking seemed more pleasant for them. Thus, the authors concluded that less active players might be more motivated to continue mobile exergaming. Yet, no evident correlation between participants' fitness and motivation was found during the SpecTrek study, but there was a correlation between participants' prior gaming experience and their perception of the tested game. Less experienced gamers felt less competent and more challenged, but at the same time more immersed with the game, which can indicate that they tend to be more motivated to play than experienced gamers, who are more likely to get bored with the game. Unfortunately, there are no available studies that would confirm or disprove these findings, and the sample is too small for making generalizations, but it is safe to assume that the game just seemed too simple for more experienced gamers, who are used to playing spectacular, large-scale games on their consoles and PCs.

4.4. Limitations of Current Study

As it has been mentioned already, one of the main limitations of this study is its little sample that does not allow to make important statistical generalizations. The only way to find meaningful relations was through previous studies performed by other researchers. Because the topic of mobile exergames is not yet thoroughly studied, there is a lack of substantial studies in this area and all of them use different approaches (e.g. samples, data collection methods), so generalizing becomes problematic or impossible, although some evident commonalities still can be found.

In future, it is necessary to involve more participants in the tests to ensure diversification and possibility to make correlations. Comparing SpecTrek with other similar games in one study, as well as comparing their effects with other physical activities e.g. walking, pacing or jogging would also prove useful.

Summary

The aim of this thesis was to raise awareness of the dangers of sedentary lifestyle and examine modern tools of facilitating physical activity in a playful way, namely exergaming and FreeGaming. A comprehensive part of the paper overviewed the history of exergames and studies of their efficiency, as well as Augmented Reality and recent developments in that field. Mobile AR was viewed as a promising technology for new active games, since it allows free locomotion in outdoor environment, giving more opportunities to physical activity, making it more efficient at the same time. The main focus was on determining advantages and disadvantages of MAR games, evaluating their potential in facilitating physical activity and discovering possible motivational factors that would attract gamers and persuade them to play such games on a regular basis.

Three existing MAR games were selected among the list of introduced mobile location-based apps and games. They were examined and the most suitable one was selected for further testing. A case study was performed in order to determine how well the selected game facilitates physical activity in players, and the Game Experience Questionnaire was applied to analyse the game in user experience perspective.

The case study demonstrated that it is possible to reach basal level of physical activity while playing the selected MAR game for at least 30 minutes, and presumably, it should take about 2 hours to reach the recommended high physical activity level. On the other hand, GEQ results showed that the game lacks in many factors that would make it more interesting, attractive and engaging for players. This is extremely important for motivating them to play it, if not on a regular basis, but at least as often as possible, and long enough to ensure fulfilment of high physical activity demands.

Overall, it can be said that MAR games indeed help players engage in PA while playing, and it is definitely better for gamers' health than typical sedentary games, but at the same time, it cannot fully substitute physical exercising in gym or fitness centre. Despite a considerable number of advantages, such as mobility, pervasiveness, affordability and use of novel technologies, MAR games often fail to engage their users and keep them motivated to play. The lack of interesting immersive story, poor feedback, absence of social interaction within the game and inability to provide flow and balance between player's skills and game challenges as well as physical capabilities and intensity of exercise – all of these factors may

loosen or completely destroy motivation to play the game. Player's background, such as fitness state or prior gaming experience also play an important role. An exergame should not require much of a player's attention while she is engaged in PA and should let her focus on exercising rather than the screen, otherwise, being too much focused on the game will make PA frustrating and, at the same time, put the player in danger. The game has to be equally interesting and immersive for gamers with different gaming experience - it should not be too challenging for newbies, but at the same time not too simple/boring for experienced gamers who have played many various games before and are harder to impress.

Further Study

The presented study is only the first step in the series of experiments and there is a lot of work to be done in the future. Firstly, it is reasonable to compare two or more different MAR games in order to see whether they yield similar results in terms of PA and UX. Secondly, comparing mobile exergaming with other types of PA, i.e. active walking outdoors, walking on a treadmill or jogging, would also help to determine the possible psychological and physiological differences in all of the listed activities. Drawing a bigger sample for the case study, engaging more researchers and moderators, and using more objective data collection instruments (e.g. more complex PA levels assessment tool to determine fitness state in participants before testing, and heart rate monitor or accelerometer for measuring PA during tested activities) would increase validity and reliability of the study and allow more meaningful data generalization.

So far, this study helped to analyse the necessary characteristics for a MAR game that would make it more appealing and provide better user experience. This information can be used in developing a new MAR game, aimed at propagating and facilitating physical activity in its players and, hopefully, making them healthier and reducing numerous risks of sedentary and low-active lifestyle. Ultimately, the discovered factors, conditions and guidelines for designing attractive, effective and motivational mobile exergames should help future researchers and game developers with their projects.

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Kokkuvõte (Summary in Estonian)

Liitreaalsuse mängud füüsilise aktiivsuse tõstmiseks

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Füüsilise aktiivsuse puudus on paljude krooniliste haiguste ja terviseprobleemide võtmeteguriks. Tänapäeval veedavad inimesed palju aega istuvas asendis – seda kas kontoris töötades või koolipingis istudes, ja lisaks sellele ka kodus diivanil mugavalt televiisorit vaadates või internetis surfates. Arvuti- ja videomängude liigne mängimine võib süvendada istuva eluviisi kahjulikku mõju meie tervisele. Hiljuti aga said populaarseks nn aktiivsed mängud (*exergames* – ingl. *exercising + games)*, mis on välja mõeldud selleks, et ühendada omavahel mängimise lõbu ja kehalise aktiivsuse tõhusus. Kuid mõned teadlased (Buddharaju & Pamidi, 2013; Barnett et al., 2013; Mortazavi et al., 2014) väidavad, et selliste mängude võimalused on siiski tihti piiratud toa väikese suurusega, mööbliga ja teiste toas olevate kõrvaliste esemetega, mis võivad mängijat takistada ja isegi vigastada. Pealegi on kõik tuntud aktiivsed mängud konsoolipõhised ja üsna kallid, ning paljudel inimestel lihtsalt puudub võimalus neid osta.

Teisiti on lood mobiiltelefonidega – 2014. aastal ületas mobiiltelefonide kasutajate arv lauaarvutite kasutajate arvu, ja see number aina kasvab. Nutitelefonide ajastu ja saavutused liitreaalsuse tehnoloogias andsid võimaluse teha aktiivsed mängud mobiilseks ja asukohapõhiseks – inimesed ei pea rohkem mängima kodus istudes, vaid saavad väljas käia, värskes õhus jalutada, suurendades sellega kasu oma tervisele. Kahjuks ei leidu tänapäeval nii palju huvitavaid ja toimivaid mobiilseid liitreaalsuse mänge, mis võiksid mängijatele tõepoolest meeldida ja motiveerida neid rohkem liikuma. Paljud uurijad (Görgu, et al., 2010; Chitaro & Sioni, 2012; Lindeman et al., 2012) on loonud ka oma mängude prototüüpe lootuses, et nad saavad aidata mängijatel tõsta nende füüsilist aktiivsust, kuid senini pole selliste mängude efektiivsust põhjalikult uuritud.

Selle magistritöö eesmärgiks on uurida liitreaalsuse mobiilimängude mõjusust ja aru saada, millised mänguelemendid võiksid aidata ligi meelitada rohkem mängijaid. Uuring vastab alljärgnevatele uurimisküsimustele:

1. Millised on liitreaalsuse mobiilimängude põhilised eelised ja puudused arvuti- ja konsoolimängudega võrreldes?
2. Kas aktiivsed liitreaalsuse mobiilimängud aitavad kaasa füüsilise aktiivsuse suurendamisele?

3. Millised on motiveerivad ajendid, mis võiksid ergutada mängijaid liitreaalsuse mobiilimänge mängima regulaarselt?

Töö on jaotatud teoreetiliseks ja praktiliseks osaks. Teoreetiline osa kirjeldab praegust olukorda aktiivsete konsooli- ja mobiilimängude vallas läbi kirjanduse ülevaate ja analüüsib teiste sarnaste uuringute tulemusi ja järeldusi. Praktiline osa on pühendatud juhtumiuuringule, milles autor testib "SpecTrek" mobiilimängu kümne osavõtja abil. Multi-metoodiline uuring, sealhulgas sammulugeja, GPS jälgimine, vaatlus, intervjuud ja mängukogemuse küsimustik, oli korraldatud osavõtjade füüsilise aktiivsuse taseme mõõtmiseks 45-minutilise mängusessiooni jooksul ning ka nende üldise mängukogemuse hindamiseks.

Juhtumiuuringu empiirilised tõendid koos teoreetiliste teadmistega näitasid, et mobiilsed liitreaalsuse mängud võivad teataval määral suurendada füüsilist aktiivsust, kuid nad ei saa täielikult asendada tegelikku liikumisharrastust. Vaatamata sellele, tundis enamik osavõtjaid huvi liitreaalsuse aspekti vastu ja nautis mänguprotsessi, väites, et mäng saaks ergutada neid rohkem liigutama. Vähemalt sellistel mängudel on suur potentsiaal edendada aktiivset eluviisi ja muuta mängijaid terviseteadlikumaks. Seetõttu hõlmab antud magistritöö lisaks ka kehalist aktiivsust soodustavate mängude eeliseid ja puudusi ning olulisi nõudmisi mängijate jaoks atraktiivsete ja kehalist koormust soodustavate mobiilimängude loomiseks.

See info võib kasulik olla ka teistele mänguarendajatele ja eespool mainitud mängude uurijatele. Magistritöö autor kavatseb kasutada saadud teadmisi oma edasises uurimistöös, kasutades suuremat valimit ja rohkem objektiivseid andmekogumisvahendeid (nt pulsikell või kiirendusmõõtur füüsilise aktiivsuse mõõtmiseks). Samuti on vajalik omavahel võrrelda mitut erinevat mängu või üht kehaliselt aktiivset mängu muu sarnase kehalise tegevusega, nagu jalutamine ja jooks. Lõplikuks eesmärgiks on arendada liitreaalsuse mobiilimängu, mis propageeriks tervislikku ja aktiivset eluviisi ning oleks huvitav ja meeldiv nii vilunud mängijatele kui ka lihtinimestele, kes soovivad suurendada oma kehalist aktiivsust, kuid ei suuda leida selleks piisavat motivatsiooni.

Magistritöö on kirjutatud inglise keeles, koosneb 6 osast, sisaldab üle 24 000 sõna, 19 joonist ja 6 tabelit ning kokku omab 56lk sisulises osas.

Võtmesõnad: exergaming, aktiivsed mängud, asukohapõhised mängud, liitreaalsus, istuv eluviis

Appendices

GEQ – Core Module

Please indicate how you felt while playing the game for each of the items,
on the following scale:

not at all	slightly	moderately	fairly	extremely
0	1	2	3	4

1	I felt content
2	I felt skilful
3	I was interested in the game's story
4	I thought it was fun
5	I was fully occupied with the game
6	I felt happy
7	It gave me a bad mood
8	I thought about other things
9	I found it tiresome
10	I felt competent
11	I thought it was hard
12	It was aesthetically pleasing
13	I forgot everything around me
14	I felt good
15	I was good at it
16	I felt bored
17	I felt successful
18	I felt imaginative
19	I felt that I could explore things
20	I enjoyed it
21	I was fast at reaching the game's targets
22	I felt annoyed
23	I felt pressured
24	I felt irritable
25	I lost track of time
26	I felt challenged
27	I found it impressive
28	I was deeply concentrated in the game
29	I felt frustrated
30	It felt like a rich experience
31	I lost connection with the outside world
32	I felt time pressure
33	I had to put a lot of effort into it

GEQ – Post-Game Module

Please indicate how you felt after you finished playing the game for each of the items, on the following scale:

not at all	slightly	moderately	fairly	extremely
0	1	2	3	4

1	I felt revived
2	I felt bad
3	I found it hard to get back to reality
4	I felt guilty
5	It felt like a victory
6	I found it a waste of time
7	I felt energised
8	I felt satisfied
9	I felt disoriented
10	I felt exhausted
11	I felt that I could have done more useful things
12	I felt powerful
13	I felt weary
14	I felt regret
15	I felt ashamed
16	I felt proud
17	I had a sense that I had returned from a journey

GEQ – Answers

Following tables contain answers to GEQ provided by the participants, prior to applying scoring procedure.

Core Module		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
1	I felt content	3	2	3	3	4	2	2	1	3	1
2	I felt skilful	3	0	4	4	4	3	3	0	3	1
3	I was interested in the game's story	1	1	2	2	4	2	1	1	2	2
4	I thought it was fun	4	2	3	3	4	3	2	2	3	3
5	I was fully occupied with the game	4	0	3	3	4	3	3	3	3	3
6	I felt happy	3	2	3	3	4	3	2	2	3	1
7	It gave me a bad mood	0	0	0	0	0	0	1	1	0	0
8	I thought about other things	1	3	1	1	1	1	2	3	0	2
9	I found it tiresome	1	2	0	1	0	1	3	3	1	1
10	I felt competent	3	0	4	4	3	3	3	0	3	1
11	I thought it was hard	1	2	0	0	1	2	3	3	2	2
12	It was aesthetically pleasing	3	0	3	3	4	1	1	1	1	1
13	I forgot everything around me	4	0	0	1	3	1	2	3	0	2
14	I felt good	3	2	4	3	4	3	2	1	2	1
15	I was good at it	3	0	4	3	3	3	3	0	3	1
16	I felt bored	0	1	0	0	0	0	1	1	0	0
17	I felt successful	3	2	4	3	3	3	3	1	3	1
18	I felt imaginative	2	0	3	2	4	3	2	2	1	2
19	I felt that I could explore things	4	0	3	2	4	4	3	2	3	3
20	I enjoyed it	4	2	3	3	4	3	2	2	3	2
21	I was fast at reaching the game's targets	3	0	4	4	4	3	2	1	3	1
22	I felt annoyed	1	1	0	0	0	0	1	1	0	0
23	I felt pressured	1	0	0	0	4	0	0	2	0	1
24	I felt irritable	0	1	0	0	0	0	1	0	0	0
25	I lost track of time	2	3	1	1	3	1	1	1	1	1
26	I felt challenged	3	3	2	1	4	3	3	3	1	2
27	I found it impressive	3	0	2	2	4	2	2	2	2	3
28	I was deeply concentrated in the game	4	0	3	2	4	3	3	3	3	2
29	I felt frustrated	0	3	0	0	0	1	1	1	0	0
30	It felt like a rich experience	4	1	1	1	4	2	2	2	3	2
31	I lost connection with the outside world	2	0	0	1	4	1	3	1	1	1
32	I felt time pressure	2	1	0	0	2	0	0	3	0	1
33	I had to put a lot of effort into it	1	1	0	0	2	3	3	3	1	3

Post-Game Module		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
1	I felt revived	3	3	2	2	3	3	3	1	3	2
2	I felt bad	0	0	0	0	0	1	2	1	0	0
3	I found it hard to get back to reality	1	0	0	0	4	1	0	0	1	0
4	I felt guilty	0	0	0	0	0	0	0	0	0	0
5	It felt like a victory	3	1	3	3	3	3	3	1	3	1
6	I found it a waste of time	0	0	0	0	0	0	0	0	0	1
7	I felt energised	3	3	1	2	4	2	1	1	3	0
8	I felt satisfied	3	2	3	2	4	3	3	1	3	2
9	I felt disoriented	2	0	0	1	2	0	0	0	0	0
10	I felt exhausted	1	0	0	0	2	2	3	3	1	1
11	I felt that I could have done more useful things	1	1	0	0	3	1	1	1	0	1
12	I felt powerful	2	2	1	1	3	2	0	1	1	1
13	I felt weary	1	1	0	1	1	1	2	2	1	1
14	I felt regret	0	0	0	0	0	0	0	0	0	0
15	I felt ashamed	0	0	0	0	0	0	1	0	0	0
16	I felt proud	2	0	2	2	3	3	2	1	2	1
17	I had a sense that I had returned from a journey	4	3	1	1	4	3	3	2	2	2

Data Summary

	Basic Background Information				GEQ – Core Module							GEQ – Post-Game Module				Game Progress & Results			
	Age	PA *	Gaming Exp. **	Freq. ***	Competence	Immersion	Flow	Tension/ Annoyance	Challenge	Negative Affect	Positive Affect	Positive Exp.	Negative Exp.	Tiredness	Return to reality	Steps	Time	Km	Result
P1	26	1	AR game(s); mobile	2	2	3	3	3	0	2	1	3	3	0	1	1822	0:33:34	1,88	**Done**
P2	26	3	Console	3	3	0	0	1	2	1	2	2	2	0	1	2124	0:22:10	1,49	**Done**
P3	29	3	Console	3	3	4	2	1	0	0	0	3	2	0	0	2017	0:28:03	1,57	**Done**
P4	25	3	Mobile; console	2	2	4	2	2	0	0	1	3	2	0	1	3225	0:32:14	2,01	**Done**
P5	25	1	—	0	0	3	4	4	0	3	0	4	3	1	2	2246	0:45:00	2,71	**Failed**
P6	24	3	Mobile; console	3	3	3	2	2	0	2	1	3	3	0	2	2768	0:34:12	2,29	**Done**
P7	21	2	Mobile	4	4	3	2	2	1	2	2	2	2	1	3	1870	0:21:05	1,52	**Done**
P8	27	1	—	0	0	0	2	2	1	3	2	2	1	0	3	2157	0:45:00	2,56	**Failed**
P9	15	1	Mobile; console; PC	4	4	3	2	2	0	1	0	3	3	0	1	1969	0:31:46	1,79	**Done**
P10	16	2	Mobile; PC	2	2	1	2	2	0	2	1	2	1	0	1	2987	0:45:00	2,62	**Failed**

* Physical Activity level, calculated with GPPAQ: (1)inactive; (2)moderately inactive; (3)moderately active; (4)active

** Gaming Experience shows what kind of digital games (console, PC, mobile, AR) participant has been playing for the last 3 years

*** Gaming Frequency, i.e. how often participant plays video/computer/mobile games (in the last 3 years): (0)never; (1)rarely; (2)occasionally; (3)weekly; (4)daily