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ImMotion
Exergame for Warm Up Guidance

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von / by

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Saarbrücken, Sunday 29th July, 2018

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Abstract

Past research related to exergames has found that they can help to motivate people to exercise by converting physical activity into an enjoyable game. However, these exergames have been single purpose usually home fitness only. In this thesis, we designed an exergame for warm up guidance to be used in gyms and fitness centers before physically more strenuous exercise. We utilized immersive technologies based on the hypothesis that they can be used as a guiding tool for warm up procedures, would increase warm up duration, and increase exercise enjoyment. In order to evaluate our exergame we have conducted two user studies. The first was an online study where we collected responses from 466 participants about their work out and warm up habits. For the second study we utilized a between-subject laboratory experiment with 10 participants and two conditions: (a) warming up by following a video with a fitness instructor guiding through a warm up session; (b) warming up by interacting with our exergame solution. The results from the exergame condition showed a statistically significant increase in exercise duration, enjoyment of the physical activity, and participant's momentary feeling of pleasure relative to the non-gaming condition. In summary, the experiment results and survey responses demonstrated that the Immotion exergame effectively guided amateur athletes through a general warm up procedure by utilizing immersive technologies and an appealing game design.

Acknowledgements

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Chapter 1

Introduction

Physical activity and exercise can have immediate and long-term health benefits. It significantly decreases the commonness of chronic diseases, serves as a countermeasure for psychological disorders, and greatly limits the severity of episodes of anxiety and depression [1, 2]. The counterpart to all these benefits is that engaging in physical activity is often associated with a higher risk of injury that can occur in athletes of all age and types [3]. However, most of the injury types can be prevented. There exist different injury prevention mechanisms that are suggested by sports professionals and physical therapists. They all agree that every physical activity must begin with a warm up procedure. This moderate activity prepares the athlete's body for the more intense exercise, improves the subsequent performance, and can decrease the likelihood of injury.

Despite the benefits of engaging in warm up before every sports activity, it is still avoided by many recreational and professional athletes. Reasons for doing so are manifold. However, it boils down that it is perceived as a boring and time consuming activity. That is, athletes lack the necessary motivation in order to perform correct warm up exersice with recommended duration on a regular basis. This suggests that educational and motivational solutions with primary focus on the benefits of warm up, including injury prevention, need to be developed and implemented in order to increase the proportion of athletes who engage in warm up routines before every strenuous exercise.

Lack of motivation may cause an athlete not to engage in warm up exercise, or not to engage at a proper intensity or for a sufficient duration. One approach to solve the motivation problem in athletes is to combine the warm up exercise and entertainment in the form of physical exercise video games (exergames) by utilizing game elements that can increase the motivation, exercise enjoyment, and engagement. Currently, there exist multiple successful commercial exergaming products [4, 5]. Also, the amount of research and publications on this topic have been increasing rapidly in recent years.

However, all these exergames are intended for home usage and general fitness. There is an absence of exergames that are specifically designed and developed to be used for warm up exercises and targeted towards individuals who avoid warming up before sports activities. Most importantly, there exist no exergame solutions that guide athletes through a proper warm up procedure. Only few studies investigated the effects of immersive technologies on exergaming and individuals motivation to engage in physical activity (e.g. [6]). These studies have shown that immersive technologies in the fitness domain have a potential to improve participant motivation because they can immerse the exergame players sufficiently so that their focus is shifted from the discomfort and exertion of the exercise towards the enjoyment of the experience. Nevertheless, as in other studies, these exergames were designed for general fitness routines, and often lacked meaningful gameplay that fits the exercise being performed. Thus, utilizing these technologies with gamification elements opens up some exciting possibilities for research on increasing motivation in athletes to engage in warm up exercises before physically more demanding activities.

Chapter 2

Literature review

The following chapter provides an overview of the past research related to Warm Up (WU), a preparatory exercise performed prior to physical activity, theories that explain players' engagement and motivation when interacting with a gamified system, and conceptually related works in the domain of commercial and non-commercial gamified solutions relevant to fitness and exercise. In other words, this section explores the overlap of five different fields such as exergames, gamification, health and fitness, injury prevention and performance improvement, and motivational psychology. This concept is illustrated in Figure 2.1.

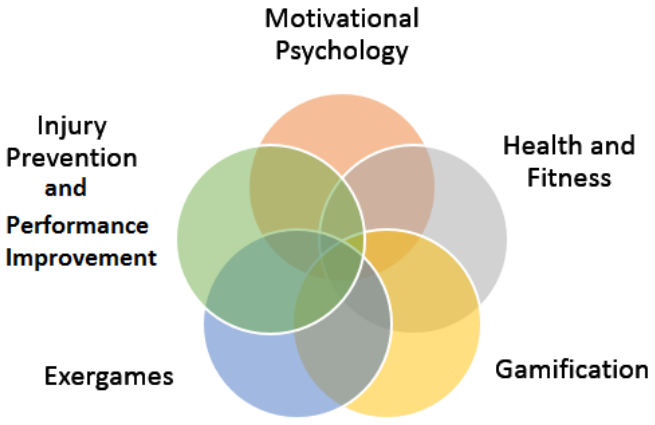

FIGURE 2.1: The five general fields that are related to this thesis. The target field is presented as the overlap of the five fields.

To impose structure, the basic concepts related to WU and an overview of studies regarding benefits of WU are given. Following, the concepts of gamification and exergames are introduced. Finally, an overview of theories that describe and explain various psychological effects that games have on players is presented together with the direction the research in this thesis will take and the motivations behind it.

2.1 Warm Up in Sports

2.1.1 The Importance of Physical Activity

In the last few decades there has been a significant increase of women and men who engage in some sort of physical activity. Physical activity is beneficial to ones health. According to medical professionals regular physical activity can significantly decrease the commonness of chronic diseases such as high blood pressure, heart disease, (colon and breast) cancer, hypertension and diabetes as well as reduce cardiovascular-related deaths, to name a few [1, 2]. Regular exercise reduces the incidence of obesity and obesity-related illnesses, maintains a general standard of health and is associated with a reduced risk of premature death [2]. Moreover, regular engagement in sports of any kind can also serve as a countermeasure for psychological disorders and greatly limit the severity of episodes of anxiety and depression [1].

2.1.2 Overview of Sports Injury

The counterargument to all of the mentioned health benefits is that engaging in regular physical activity is often associated with a higher risk of injury which can occur in athletes of all age [3]. To put it differently, there exists a higher risk of injury of the musculoskeletal system including soft tissue damage, fractures, ligament and tendon tears, and nerve injuries in athletes who engage in some sort of physical (sport) activity [1]. Sport related injuries generally occur in joints: the knee, ankle, hip, shoulder, elbow, wrist and spine, usually from a sports related accident but often due to overuse, repetitive microtraumas that are solely insufficient to cause macroscopic injuries [1]. During international athletics championships between 2007 and 2014, data regarding injuries has been collected in order to compare the characteristics of injuries between female and male athletes [7]. The results showed that males suffered more thigh strains than female athletes and that injury incidences differed between genders for location, type, and event groups. The results concerning main injury locations for female and male athletes are presented in Figure 2.2. The type of the injury depends on many factors and usually is divided into: *intrinsic* and *extrinsic* [1, 8].
Generally, extrinsic injuries are linked to the practice of sports itself and the environment the activity is carried out. On the other hand, intrinsic injuries are tied to biological characteristics, anatomical factors, gender, and age, among others [1]. Other sports specialists group sport related injuries differently. For instance, [9] differentiate between *damage* as an overuse injury and *injury* as an acute injury. They further state that an injury occurs in a single acute action (acute injury), while damage appears after repeated action as the result of many repetitive minor insults (overuse injury) [9]. Addtitionally, [10] state how "*the main characteristic of an injury is acuteness, whereas damage has a chronic character*".

Acute injuries are more likely to occur in sports that include high-speed running, rapid movement, or full-body contact, whereas aerobic low-contact sports that include long training sessions may produce overuse injuries [1].

FIGURE 2.2: Main injury location for female and male athletes during international athletics championships from 2007 to 2014. Adapted from [1]

In order to prevent injuries, athletes should receive the correct amount of training and recovery period, and have a healthy lifestyle. The correct amount of training depends on the type of the physical activity itself, as much as the physical characteristics of the athlete. Moreover, the sports technique must be correct and a good quality equipment that is adapted to the player (morphology and level of play) must be used in order to prevent injuries. Injury prevention strategies should be gender-specific. That is, as discussed in [7] and presented in Figure 2.2, for injury prevention "*one size does not fit all*", and hence it should be adapted to the differences in injury characteristics between female and male athletes. Lastly, as one of the main sports injury prevention mechanism different studies outline that every physical activity must be preceded by a suitable WU procedure. This preparatory activity is hypothesized to give athletes sufficient time to adjust and prepare for a more intense susbsequent activity thereby reducing the likelihood of injuries [1].

Next, a definition and an overview of WU prior sports activities, together with its types and major benefits is presented.

2.1.3 Defining Warm Up

Despite very contrasting beliefs and limited scientific evidence regarding its effectiveness in many situations, WU has become a standard practice among professional and recreational athletes [11, 12, 13]. WU in sports is defined as a period of preparatory exercise which is carried out in order to prepare the athlete for the demands of the subsequent physical activity [14, 15, 16]. Typically, WU includes a short and low-intensity preparatory activity which is followed by a stretching routine and sports specific exercise [17]. The ideal WU depends on the physical activity performed, the level of competition, and the age of the participants. Moreover, the ideal WU should include the muscle groups that are required during the training or competition [1]. Various studies point out that the main purpose of WU is to enhance the subsequent competition or training performance and improve muscle dynamics to reduce the risk of sport-related injury [11, 13, 18]. Nonetheless, there is still deficiency of scientific evidence on what kind of WU can influence both muscle damage prevention and performance improvement [17].

The following section will gives an overview of some of the assumed benefits of WU as a preparatory routine before physically more demanding exercise.

2.1.4 The Benefits of Warm Up

In a systematic review and meta-analysis of relevant studies concerning the benefits of WU on performance, [19] found that an adequate WU supports an improvement in performance in 79% of the research studies analyzed. Furthermore, they pointed out that there exists little evidence supporting detrimental effects WU might have on performance and sports participants. WU can affect the performance via variety of temperature and non-temperature related mechanisms [11]. The most relevant effects of WU can be attributed to physiological mechanisms like increased muscle temperature, decreased resistance of muscle and joints (decreased stiffness), increased oxygen delivery to muscles, increased nerve-conduction rate and speeding of metabolic reactions [11]. However, the benefits of WU are not exclusively physical. Apart from the physiological changes a body undergoes during this preparatory period, it has been hypothesized that a possible psychological benefit can also be gained by following a proper WU routine [11, 13]. It has been suggested that WU can serve as a preparatory phase providing time for athletes to concentrate and mentally prepare for the forthcoming exercise [13]. Moreover, in the study that investigated the link between a WU and psychological processes [20], it has been reported that athletes who performed a proper WU routine before engaging in more demanding physical activity demonstrated significantly higher levels of exercise related motivation and enjoyment. Thus, increased motivation and enjoyment is an additional psychological benefit of WU.

Apart from physiological and psychological benefits, WU has been suggested to have an important role in sports-related injury prevention [13]. Unfortunately, there exist no high-quality research studies in order to draw a definite conclusion as to the effect of WU on sports-related injury prevention [21]. In [19] the researchers reviewed five high-quality studies that investigated the effects of warming up in humans on injury risk in physical activity. Five studies reported sufficient data on the effects of warming up on reducing injury risk in humans. However, only three of the studies found that performing a WU prior to performance significantly reduced the risk of injury in athletes, while the remaining two found that warming up has no effects in injury decrease [19]. Therefore, the researchers concluded that there is insufficient evidence to endorse or discontinue WU routine prior to physical activity in order to prevent injury among sports participants. However, the weight of evidence is in favor of a decreased risk of injury. A possible bio-mechanical explanation for injury reduction with WU has been presented in [17]. The results of this study showed that warmed-up muscles in the animal models can elongate more before failure caused by increased force and length of stretch.

2.1.5 Types of Warm Up

There exist various types of WU procedures that professional and recreational athletes at any level use as a preparatory phase before the physically more demanding exercise. According to [17], an appropriate WU procedure should consist of three factors. These factors represent the WU components mentioned most often in the sports literature. However, recent studies question the importance and appropriateness of stretching as a component of a proper WU procedure [22]. The components are as follows:

- a period of aerobic exercise to increase body temperature [17],
- a period of sport-specific stretching to stretch the muscles to be used in the subsequent performance [17] and
- a period of activity incorporating movements similar to those to be used in the subsequent performance [17].

First, it is important to distinguish between WU and stretching activities. While WU mainly focuses on core body temperature elevation, stretching involves movements that stretch the muscle in order to increase the range of motions of joints or group of joints [18]. Generally, WU procedures can be classified into *passive* and *active* WU procedures and are centered on increase in core and muscle temperature. They accomplish this objective through different approaches. The former involves raising muscle or core temperature by some external means (e.g. hot showers, saunas), while the latter aims to increase the body temperature through active movements of the major muscle groups (e.g. jogging, cycling, swimming) [12, 13].

The most effective WU that could potentially affect the subsequent performance generally depends on the duration, intensity, and the nature of the sports activity to be performed [12]. As each sport has its own unique requirements, it is difficult to specify a general WU routine that is beneficial and has a positive impact by maximizing the subsequent performance. Nonetheless, it is suggested that a proper WU should use general, whole-body movements and last five to ten minutes, followed by a five minutes recovery period [12]. However, in cold weather, the duration of the WU procedure should be increased [1]. One example of WU procedure widely used in football which is easily adapted to other sports is the FIFA 11+ Warm Up Program (FIFA 11+), developed in cooperation with national and international experts under the leadership of the FIFA Medical and Research Centre (F-MARC), in order to reduce the incidence of football injuries and maximize the subsequent performance [23]. The program includes various exercises that focus on core stabilization, and eccentric training of thigh muscles, to name a few. A recent review [24] showed how the FIFA 11+ program can decrease the incidence of injuries in amateur football players and also improve neuromuscular performance, enough to consider this program a fundamental public health intervention.

Although considering the aforementioned benefits and the fact it is widely recommended to undertake the practice of WU, many amateur and recreational athletes do not seem to perform a proper WU before an exercise [25]. The reasons for this are manifold. Some people do not realize the importance of WU, find it tiresome or being pressed for time and eager for instantaneous results, start with the more strenuous activity immediately. A recent survey [25] which included 1040 golfers and their WU habits revealed the most common reasons for not warming-up. The survey showed that out of all the questioned golfers, over 70% never or rarely warm-up. The most common reasons for not performing a proper WU routine were the perception that WU is needless (38.7%), lack of time (36.4%) and that they do not want to be bothered with this routine (33.7%). These results suggest that educational and motivational solutions with primary focus on the benefits of WU, including injury prevention, need to be developed and implemented in order to increase the proportion of athletes who engage in WU routines before every strenuous exercise. One possible solution is the usage of *Gamification* and *Exergames* in motivating athletes to perform WU more regularly.

2.2 Gamification and Exergames

Having outlined the basic concepts of WU procedures, the following section discusses the dimensions of gamification and exergames. In order to tie in with the idea of linking these concepts with WU procedures, the emphasis will also be placed on understanding the fundamental aspects behind human's motivation and engagement (Section 2.3).

2.2.1 Video Games and Exercise

At first glance, most people think of video games and exercise as two concepts that are polar opposites and cannot coexist together. Exercise and sports are usually associated with being physically active and burning calories. On the other hand, video games are often linked to activities that involve hours of sitting down by your self to play, for example, *World of Warcraft*[1]. However, these two concepts can actually complement each other. In both instances, one is seeking to be better at the task being performed. For example, an athlete will try to improve its best running time, and the video gamer will strive to beat its best game score. The missing link, that connects these activities together, is given in a form of gamification which leverages people's natural desires for competition, socializing, learning, mastery, achievement, status, self-expression, and closure in order to encourage and motivate individuals to exercise more frequently and improve their overall health.

2.2.2 A Primer on Gamification

In recent years, there has been a tremendous increase in popularity of video games inspired software solutions designed to address issues in a variety of functional areas, incentivize consumer behavior or increase motivation and the desire for achievement. What these software solutions all have in common is that they are based on the concept of gamification. This term began to rise in popularity in 2010 (Figure 2.3), and since then has been a trending topic [2]. Gamification is being used and studied in various domains, from education and academic performance to health care, finance, company culture building, and recruitment, to name a few [26, 27, 28]. Large companies like *Nike* [29], *Deloitte* [30], *Starbucks* [31], *Coca Cola* [32], and *Toyota* [33] have all used gamified solutions in order to increase customer loyalty, change behaviors, and drive innovation.

[1] Or even *Flappy Birds*

[2] Data source: Google Trends, www.google.com/trends

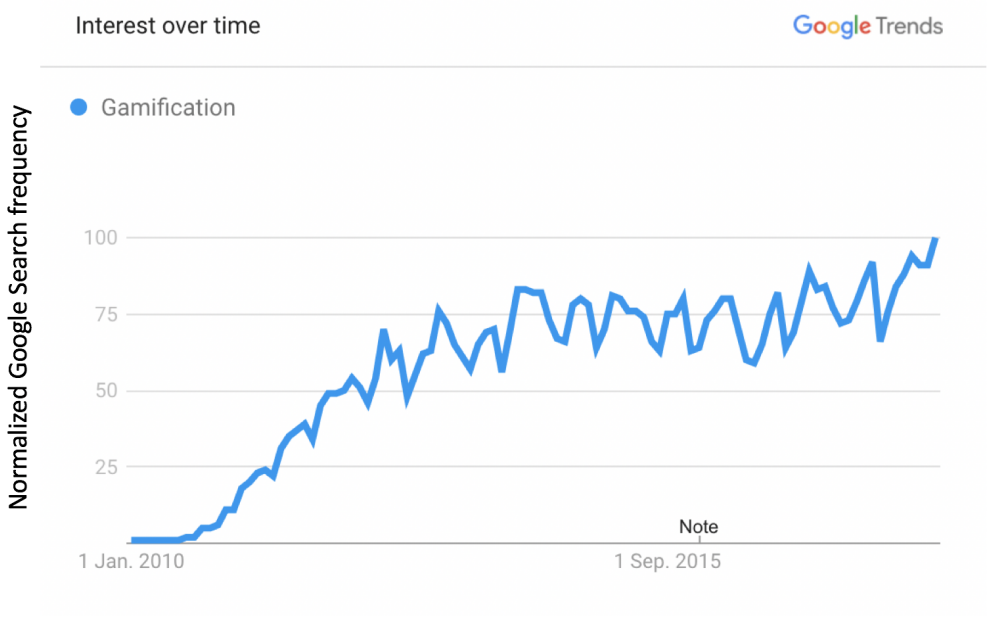

FIGURE 2.3: Google search frequency of the term "gamification" from January 2010 through August 2018.

Gamified solutions for sports activities are becoming popular and widely used also, and according to [34] the consumer segment comprised of millennials [3], have the highest inclination towards iOS fitness mobile applications (Figure 2.4).

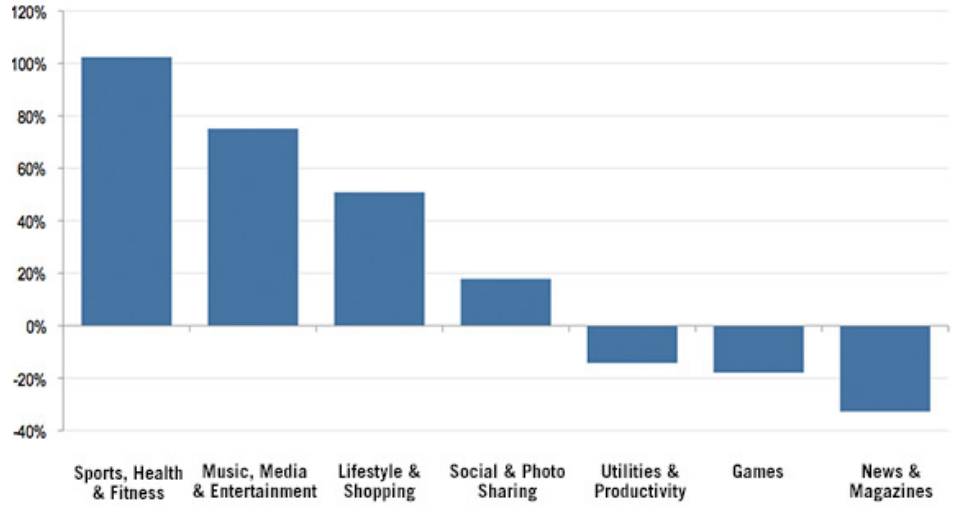

FIGURE 2.4: Random sample of 15.271 American iOS owners. Adapted from [34]

An example of gamified solution for sports and exercise is the *Strava* application and website that uses gamification elements in order to enhance the experience of sport and connect athletes with similar sports affinities from around the world [36]. Moreover, there is an increasing number of startups [37, 38] that have gamification at their core or offer assistance to enterprises to gamify their existing services [39].

[3] Also known as Generation Y. A demographic cohort born between 1980s and the mid-1990s to early 2000s [35]

The increasing popularity of gamification related researches in the academia has also been reported in [40]. Figure 2.5 gives an overview of the increase of writing on this topic. It includes only the number of publications for every year for the term "gamification" and excludes patents and citations [4].

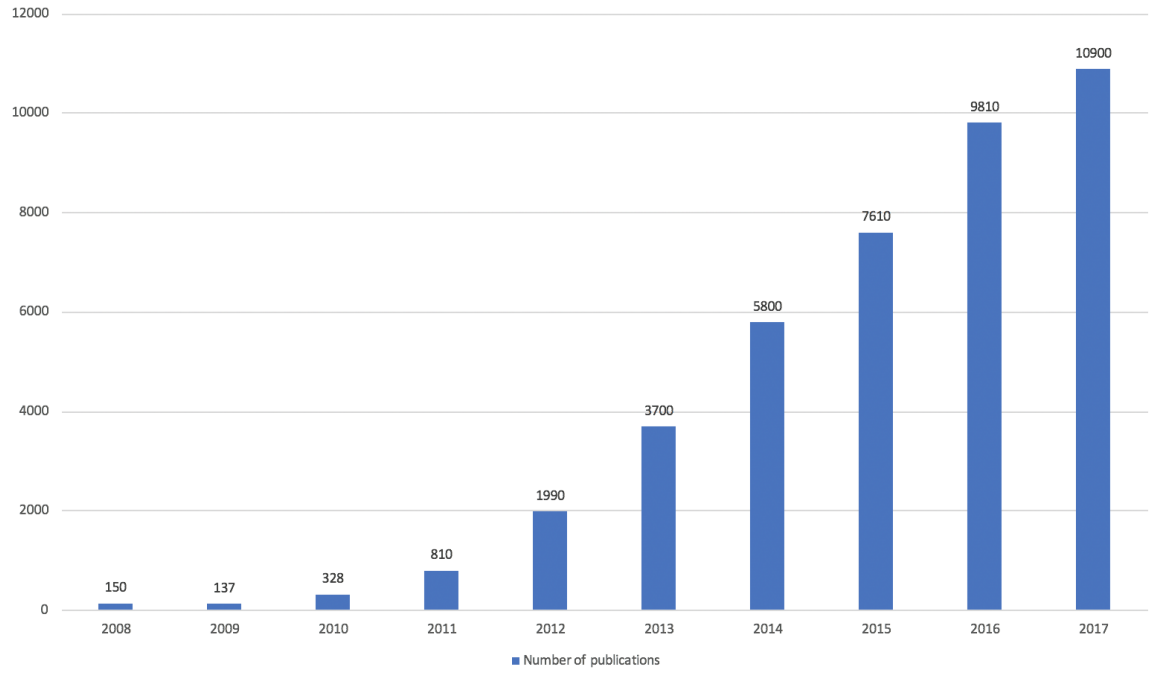

FIGURE 2.5: Search hits on term "gamification". Adapted from [40]

It is worth noticing that the appearance of the term "gamification" in publication titles has been increasing more rapidly than search hits for the same term (Figure 2.3). This suggests that gamification is becoming more popular in academic circles as a research topic.

Defining Gamification

There exist references to *gamifying* online systems as early as 1980. Professor Richard Bartle from University of Essex, points out the word referred originally to "*turning something not a game into a game*" [41]. The first use of gamification in its current sense dates back to 2002 by Nick Pelling as part of his consultancy business. However, the term did not see widespread adoption before the second half of 2010 [42]. In parallel with this term, a verb *to gamify* emerged. Its meaning refers to applying game mechanics to supercharge user engagement, loyalty and fun [43]. As the term itself is relatively new, there exist numerous definitions of gamification [44, 41, 45]. A definition introduced by [44] is currently the most cited one in academia, and is the definition that is adopted for this thesis.

[4] Data source: www.scholar.google.com

In their paper [44], the authors proposed a well reasoned definition as follows:

"Gamification is the use of game design elements in a non-game context."

It should be noted that the definition outlined by the researchers relates to *games* and not *play* [44]. Even though often used interchangeably, and there exists a complex relationship between these two concepts, a clear distinction can be made. That is, according to the forms they take in the world, *play* can be interpreted as a broader category that includes *game* as a subset [46]. Play is normally assumed to be a free-form activity lacking constraints engaged in for pleasure and amusement rather than a serious or practical purpose whereas games provide context for actions and are limited in action by fixed rules [47]. In addition, [46] define game as a system where players engage in an artificial conflict which is defined by rules that limit players' behavior and define the game that can result in a quantifiable outcome or goal. Games manifest themselves as integrated experiences, but they are built from many smaller pieces often called game elements [41]. They represent parts of games used as a building blocks for creating gamified applications, as well as tools and rules that define the overall context of game [48]. This means that the definition given by the authors makes clear distinction between gamification and other systems that employ full-fledged games rather than elements of game design only [5].

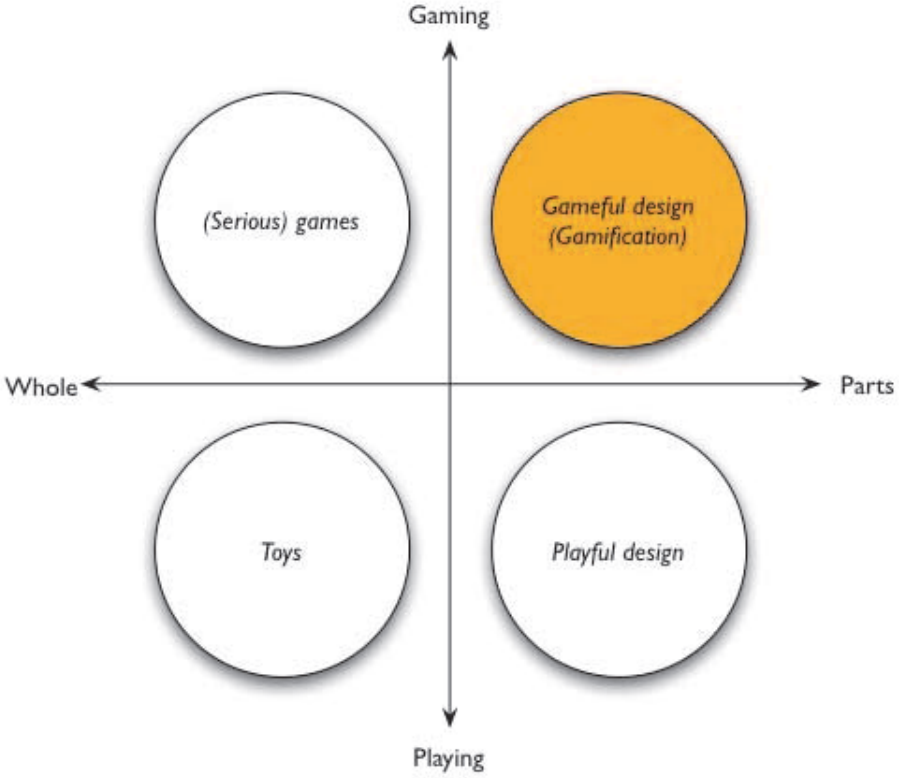

FIGURE 2.6: The matrix distinguishing the concepts related to gamification [44].

[5] Data source [44]

Furthermore, it does not include all game elements either. Based on the definition, gamification includes only a subcategory of elements called game design elements that are used as seen appropriate in the current situation. The final aspect of the definition is that gamification operates in "*non-game context*". A non-game context refers to applications which main purpose is beyond pure entertainment. That is, using game design elements in a context "*other than games*". This implies that gamification can be used and successfully applied to almost anything: from business, finance, personal improvement to education, health, and fitness [44]. Thus, the challenge of gamification is to select elements that normally operate within the game universe and apply them effectively in the real world. The concept of gamification is closely related to similar pre-existing concepts such as serious games, playful design, and toys. The proposed definition aims at separating the concept of gamification from similar phenomena on a two-by-two matrix. In Figure 2.6, along one axis a distinction between gaming and playing is made, and on the other between whole game and an artifact with game elements. Gameful design or gamification differs from playful design because the former focuses on activities that are goal oriented and structured by rules while the latter focuses on activities that are based on improvisation and are free of form. Moreover, gamification is situated in the quadrant involving games and game elements, meaning that gamification makes use of gameful design rather than playful design and game elements rather than full-fledged games. This is different to serious games used also in non-game contexts, a group that includes full games that have been created for reasons other than pure entertainment. One thing to point out is that even though gamification utilizes game principles and design elements, it is envisioned and developed as a process which sole purpose is far removed from the objectives' of traditional game design [49]. Hence, the process of gamification design is partly different from game design since the former is being used to enhance engagement in various "*non-game contexts*" and is directed towards achieving a particular goal, whereas the latter starts from the desire to make something that people will enjoy and is completely directed towards pure entertainment [49, 50].

2.2.3 A Primer on Exergames

Recent progressions in ubiquitous technologies offer a solution that could dispute a number of potential barriers preventing individuals to engage in regular physical activities. This solution comes in a form of video games that are developed for a certain purpose other than entertainment alone, mainly for the context of health and fitness, named exergames. They represent enjoyable tools that can increase the energy expenditure during game play, motivate players to engage in physical activity more regularly, promote social interaction, and even enhance cognitive performance [51]. Compared to the term gamification, the term exergame or *exergaming* has been known for a while, and its roots can be found in games released in the late eighties.

The name exergame is a concatenation of the words *exercise* and *game*, sometimes referred to as Active Video Gaming (AVG) [52]. This genre includes video games with the aim of encouraging and facilitating physical activity which rely on technology that tracks body movement [52]. A large amount of research has been put into exergames development, and there exist several successful commercial products today. The *Nintendo Wii* [4], released in November 2006 for the home entertainment market was the first mainstream game console which contained a built in exergaming system. Nintendo Wii exergame contributed to a 73% increase in Nintendo's net sales, with 24.5 million consoles and 148.4 million software units sold to date, making it the second highest selling video game in 2007 [51]. Apart from exercise, exergames have been used in fields such as art and education [52]. Researches found the the usage of exergames in these fields has led to the development of educational and social skills [52]. Playing exergames can increase caloric expenditure, heart rate, and coordination. While psychosocial and cognitive impacts of exergames may include increased self-esteem, social interaction, motivation, attention, and visual–spatial skills [51]. Over the recent years, the usage of exergames has also been studied for their potential health and rehabilitation benefits. This includes a diverse patients population, such as individuals with multiple sclerosis, Parkinson's disease, stroke, and obesity [53, 54, 55]. Taking into account all the mentioned benefits one can gain with exergames, it is understandable that there is also an increase of writing on this topic (Figure 2.7). As in Figure 2.5, this one includes only the number of publications for every year for the terms "exergame" or "exergaming", and excludes patents and citations [6].

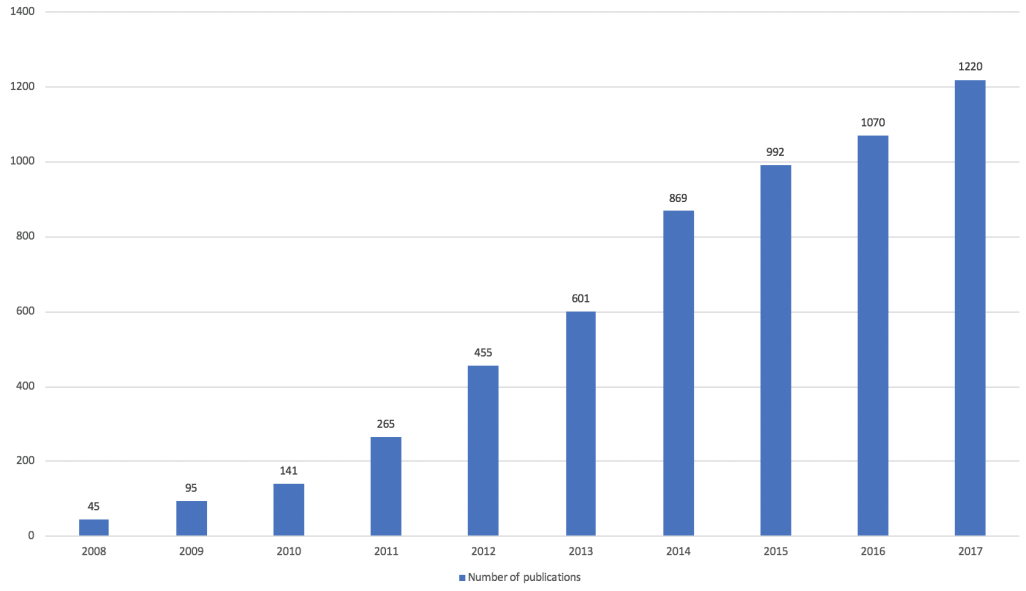

FIGURE 2.7: Search hits on term "exergame" or "exergaming".

[6]Data source: www.scholar.google.com

Exergames do an excellent job of implementing various gamification techniques that play off person's desire to master certain skills or achieve a specific goal. By breaking down the barriers to traditional exercise and workouts, they have the potential to promote physical activity and stimulate behavioral change, within a fun, enjoyable and motivating context. Researchers agree how incorporating exergames into schools, fitness centers, and homes can promote healthy youth development and even combat the childhood obesity crisis [51].

Defining Exergames

The goals that are set in exergames can only be achieved through body movements that are performed by the user. Hence, it is understandable that, as [56] point out, "*one of the most prominent fields where gamification and other gameful approaches have been implemented is the health and exercise field*". Even though known for decades, due to the technological advancements which allow more widespread and affordable usage of motion based controllers, these gameful systems and approaches that involve physical activity as the means of interacting with the game, commonly known as *exergames*, have only been proliferating in recent years [56]. According to [57], the main reason for increased interests in exergames is the concern over high levels of obesity in Western society. Apart from high calorie diet, physical inactivity is considered to be the main reason for obesity, especially among children. Since playing video games is a common leisure time activity among people of all ages, it has been argued by researchers [57] that video games are one of the main reasons for the decreased level of everyday physical activity and hence, increased level of obesity [58]. This is what the emerging exergames genre tries to change by encouraging players to perform physical movements during gameplay [57]. Exergames can be defined as "*video games that require physical activity in order to play*" [59]. However, a more precise definition of exergame is introduced in [59]:

> *"An exergame is a video game that promotes (either via using or requiring) players' physical movements (exertion) that is generally more than sedentary and includes strength, balance, and flexibility activities.".*

The authors [59] also define exergaming as an:

> *"experiential activity where playing exergames, videogames, or computer-based is used to promote physical activity that is more than sedentary activites and also includes strength, balance, and flexibility activities".*

The main goal of exergames is to motivate people to exercise by providing a "*safe, entertaining and engaging fitness atmosphere*" [52]. Thus, one of the challenges of exergame is to make a game appealing to players, and at the same time, make it effective and adequate as an exercise.

The player forms the root of gamification as well as exergames and, in any system, the outcome is affected and driven by his motivation [60]. Therefore, to understand the potentials and fundamental aspects behind gamification and exergame, one important part is to understand what drives people's motivation. Thus, in order to create an effective gamified system, one needs to understand how human nature works and how it can be influenced and shaped. For this reason, the next sections introduce different views from psychology about motivation, explain what has to be considered in terms of truly engaging individuals and how gamification can use this in order to achieve its purpose.

2.3 Theories of Motivation

In this section we provide a suitable overview of the subject itself and introduce terms that will be used later in the discussion. We also present theories that describe and explain various psychological effects that games have on players and how they can be used to enhance user's engagement and motivation when interacting with a gamified system. Two important theories that are regarded as crucial foundations for the concept of *gamification* are presented. First, the Self Determination Theory (SDT) by Richard M. Ryan and Edward L. Deci is introduced [61, 62, 63, 64]. Following, The State of Flow (FLOW) by Mihaly Csikszentmihalyi is reviewed and discussed [65].

2.3.1 The Rules of Motivation

The main purpose of gamification is to "*help people get from point A to point B in their lives*", whether it is visiting the gamified system more often, learning a new language, or exercising more [66]. Gamification is about stimulating individuals to act in a certain way, or at least to develop an inclination for a certain behavior. The root of gamification is human motivation.
The word *motivation* originates from Latin *motivus* and stands for "*serve to move*". In other words, motivation can be interpreted as "*to be moved to do something*"[62]. It can be defined as "*those forces within an individual that push or propel him to satisfy basic needs or wants*" [67]. One of the most influential researchers in the domain of human motivation and behavior, Richard M. Ryan and Edward L. Deci, argue that people "*can be moved*" to act by various types of factors, as so with highly diverse experiences and consequences [62]. For example, people can be motivated because they value the activity they perform, or because there exists some external influence and pressure. Furthermore, they point out that each person has different amounts and also different types of motivation. That is, each person is different in *level* (i.e. amount) and *orientation* (i.e. type) of their motivation, whereas orientation might be a goal which gives rise to action and therefore governs human behavior. Gamification taps exactly in these forces within individuals that push or propel them to satisfy certain needs or wants.

It exposes complex, but learnable, systems that individuals can engage with to achieve personal mastery and, hence, meet their objective [66]. There exist various motivation theories that address different aspects of motivational properties of gamified systems. However, only two theories are further discussed in detail because they have already been applied to great number of digital systems which makes them a good starting point in understanding well gamification and its influence on players' motivation.

2.3.2 Self Determination Theory

One of the most influential motivational theories is the Self Determination Theory introduced by Ryan and Deci [61, 62, 63, 64]. It is an empirically derived theory of human motivation that makes distinctions between different types of motivation in terms of reasons and goals that cause the respective action. That is, SDT argues that intentional human behaviors might vary in the extent to which they are *self-determined* versus *controlled*. This means that behaviors can vary in the extent they are experienced as being freely chosen and coming from one's self, in contrary to being pressured or controlled externally. When these behaviors are experienced as freely chosen they are considered self-determined or autonomous whereas the extent they are experienced as coerced, they are considered controlled [61]. Having this in mind, SDT distinguishes between *intrinsic* and *extrinsic* motivation [62]. The first type of motivation, as the word *intrinsic* already suggests, refers to performing an activity for the inherent satisfaction. When intrinsically motivated, a person is moved to act because the activity is challenging, interesting and enjoyable on its own rather than because of some external prods, pressures, or rewards. On the other hand, extrinsic motivation refers to performing an action because it leads to "*separable outcome*" [63]. That is, there is some external reward or influence which drives the person to accomplish the task. The comparison between people intrinsically and those extrinsically motivated reveals that the former have more interest, excitement, and confidence which in turn, can not only enhance performance, persistence, and creativity but consequently boost vitality, increase self-esteem, and general well-being [63]. Though this division is for most people intuitively understandable, it is not always as clear as it may seem. For example, as the SDT theory states, "*motivations are fluid*". Hence, people can convert extrinsic motivators to intrinsic if they internalize the desire to do so. To put it differently, in a situation where the extrinsic motivator is found meaningful, pleasurable, and consistent with a person's worldview, it can be perceived and adopted as if it was intrinsic [68]. Although, in one sense, intrinsic motivation can exist within an individual, in another sense, it can exist in the relation between the individual and the activity one performs. Having that in mind, it is important to point out that not everyone is intrinsically motivated for the same activities and that not everyone is intrinsically motivated for any particular activity [62].

In SDT, the *basic psychological need satisfaction* is assumed to be the core motivational mechanism that directs human's behavior. SDT postulates three innate psychological needs (Figure 2.8), that are "*essential for ongoing psychological growth, integrity, and well-being*" and all three of them play a necessary part in optimal development, hence none can be disregarded without significant negative consequences [64]. These needs are the need for *autonomy*, *competence* and *relatedness*. When individuals experience them, they become self-determined and intrinsically motivated to pursue things that interest them the most [64].

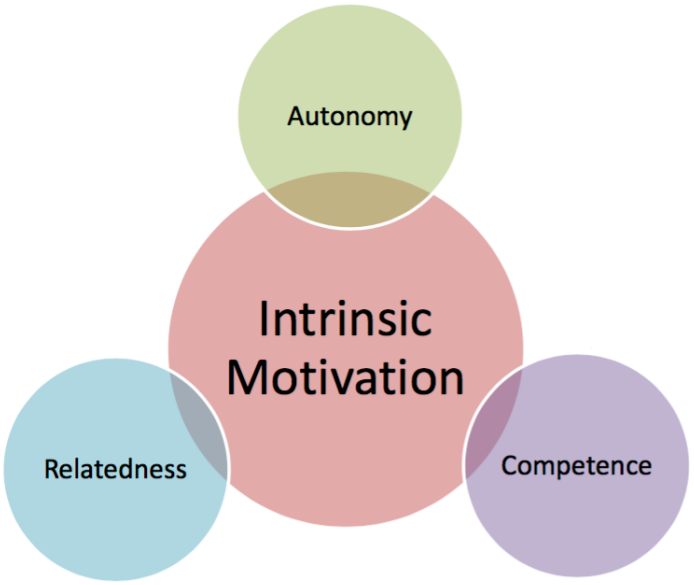

FIGURE 2.8: Basic psychological needs according to Ryan, R.M. and Deci E.L. [61]

The basic psychological needs according to Ryan and Deci are as follows [61]:

- **Autonomy** represents individuals' innate desire to feel "*free*", to experience a sense of choice and psychological freedom when carrying out certain activities [64]. Situations in which individuals are provided with the opportunity to choose freely, accompanied with a positive feedback, have been shown to influence and improve autonomy and, hence, the intrinsic motivation of individuals [63]. For example, students are autonomous when they willingly spend time and energy for completing their assignments.
- **Competence** represents individuals' innate desire to feel "*effective*" when interacting with the environment. For example, students are competent in cases when they feel they can meet the challenges of their schoolwork. Furthermore, Ryan and Deci point out that positive feedback can signify effectance and provide a satisfaction of the need for competence and consequently enhance intrinsic motivation. Contrarily, negative feedback that convey ineffectance, tend to diminish the sense of competence and hence undermine individuals' intrinsic motivation.

- **Relatedness** corresponds to experiencing meaningful "*connection*" to others. To put it differently, relatedness corresponds to ones innate need to to be a member of a group, to love and care, and to be loved and cared for [69]. This psychological need is satisfied when individuals experience a sense of togetherness and develop a close relationship with others.

The specification of autonomy, competence, and relatedness is important because it allows the prediction of variables that can affect individuals' intrinsic motivation and the development of their extrinsic motivation [61]. Gamification and exergames achieve these needs by means of diverse game elements, which will be discussed in detail in the subsequent sections.
Despite the observable evidence that humans, in general, can have intrinsic motivational tendencies towards some activities, this bias appears to manifest only in certain conditions and circumstances. Hence, SDT also places much emphasis on understanding conditions that enhance and sustain versus subdue and diminish intrinsic motivation [62]. A sub-theory of SDT called Cognitive Evaluation Theory (CET) focuses on social and environmental factors that promote or undermine this type of motivation. It uses language that reflects the assumption that intrinsic motivation is rather catalyzed than caused when individuals are in appropriate socio-enviromental circumstances [62, 63]. In other words, intrinsic motivation does not occur by itself, but represents the outcome of one's interaction with the environment and one's interests and preferences. That is, intrinsic motivation "*will flourish if circumstances permit*" [63]. Furthermore, CET, which focuses mainly on the fundamental needs for competence and autonomy, argues that interpersonal events and structures, such as rewards, communication or feedback can increase intrinsic motivation for certain actions because they satisfy the basic psychological need for competence. Accordingly, it is predicted that optimal challenges, positive feedback and freedom from degrading evaluations promote intrinsic motivation, while tangible rewards, threats, deadlines and directives decrease it [63]. CET also argues that the satisfaction of the psychological need for competence will not enhance intrinsic motivation unless it is joined by a sense of autonomy. Hence, people must perceive that their behavior is self-determined in order for intrinsic motivation to be maintained or enhanced. In other words, for a high level of intrinsic motivation, the needs for competence and autonomy must both be satisfied [63]. It is important to point out, as stated by Ryan and Deci, that people will be intrinsically motivated for certain activities only when they are intrinsically captivating for an individual. This includes activities that offer a degree of novelty, challenge or aesthetic value. Activities that do not provide such appeal, will not be experienced as intrinsically motivated.
Even though intrinsic motivation is of great importance, most of the activities people engage in are not intrinsically motivated. Such activities require an *external push* in order to be realized. This motivation, contrary to intrinsic motivation which refers to doing an activity simply for the enjoyment of the activity itself, is known as *extrinsic* motivation. It refers to performing certain activities because it is expected to result in some additional outcome or reward that have an instrumental value for the individual performing that action [63].

In general, extrinsically motivated behaviors are those which would not happen instinctively, and hence must be prompted by an intrumentality [61]. Various studies demonstrated that in specific circumstances extrinsic motivation can sustain intrinsic motivation, thus suggesting that extrinsically motivated behaviors can also be self-determined [61]. Extrinsically motivated behaviors become self-determined through the process of *internalization* and *integration*. Internalization involves transforming external regulatory processes into internal regulatory processes, while integration corresponds to the process of integrating these newly internalized values and regulations into one's self [61]. There exist four types of extrinsic regulation that can result from different types of internalization and integration, which were introduced within SDT as a subtheory called Organismic Integration Theory (OIT) [61, 62, 63]. For instance, students who work on their assignments because they personally understand its importance for their future career and those who do it only to adhere to their parents' control are both extrinsically motivated. Even though both cases involve instrumentalities rather than enjoyment, the former entails personal endorsement and a feeling of choice while the latter is associated only with an external regulation.

Figure 2.9 illustrates the OIT taxonomy of motivational types arranged from left to right in terms of the degree to which the motivation originates from the self (i.e. are self-determined).

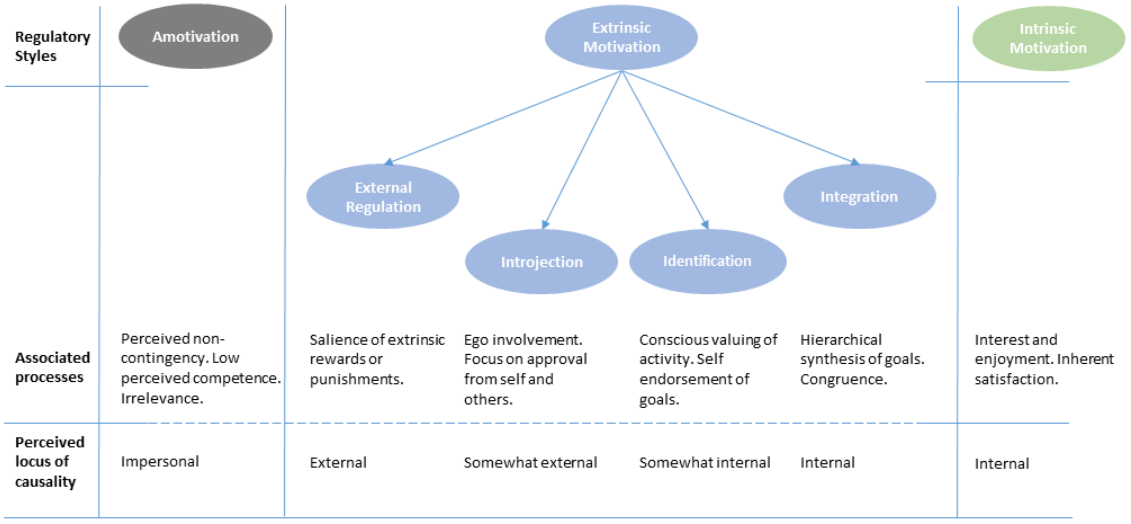

FIGURE 2.9: Types of motivations based on Self-Determination Theory by Ryan, R.M. and Deci E.L. Adapted from [62]

First, the extrinsically motivated behavior that is the least autonomous is known as *external regulation* and is regulated through some external means, such as rewards and constraints. For example, an athlete who participates in the Olympics only to obtain a medal represents an instance of externally regulated behavior. In case of *introjected regulation*, individuals begin to internalize the reasons for their action. However, this internalization only replaces the external source of motivation with an internal one, such as guilt, worry or shame.

That is, when people are motivated to perform activity in order to maintain feeling of worth. An example for introjection is an athlete who goes to the practice just because she would feel guilty if it has been skipped. A more autonomous type of extrinsic motivation, *identification*, manifests when a person identifies with the importance of some behavior and accepts it as a personal regulation only because it benefits the person in achieving a specific goal. An example for this behavior is an athlete who does not like weight lifting, but nevertheless chooses to to do it because it will positively impact her future performance. *Integrated regulation*, the most autonomous of extrinsic motivation that shares many qualities with intrinsic motivation, is a form of motivation that arises when an individual has fully assimilated the identified regulation within herself. An example of integrated regulation is an athlete who chooses to postpone the night out with friend in order to be in good shape for the next day's tournament. Integration together with intrinsic motivation represent the core for self-determined functioning and they both share the qualities that constitute self-determination. Even though they might seem quite similar, they are different in the sense that intrinsically motivated behaviors are "*autotelic in nature*" while, on the other hand, integrated behaviors are "*instrumentally (though freely) performed*" for the outcome that is self satisfactory. Finally, the self-determination continuum is closed with *amotivation* which represents "*non-regulation*" from the SDT perspective as it refers to a state where intentions to act are non existent. A person amotivated towards exercise would not exercise at all, or engage in exercise in a passive and disorganised manner [61, 62, 70].

Having outlined the basic concepts behind SDT, the next section covers the theory of *flow*.

2.3.3 State of Flow

Another approach for describing the foundations of motivation is The State of Flow. Mihály Csíkszentmihályi, one of the most recognized game psychologists and a professor at University of Chicago, described in 1975 for the first time the phenomenon of *flow*. Being fascinated by artists who would essentially get lost in their work Csíkszentmihályi argued how, creative people might differ from one another in many ways but they always have one thing in common. They love what they do. Their love for a particular activity is not because of a potential outcome or a reward. What drives them is solely the opportunity to do what they enjoy doing [65]. Athletes often refer to this concept as "*being in the zone*", religious mystics as "*being in ecstasy*", artists and musicians as "*aesthetic rapture*" [71]. After a series of studies, based on the individuals' responses regarding their emotions while performing certain activity they enjoy, Csíkszentmihályi developed a theory of optimal experience based on the concept of *flow*, which he describes as the

> "*the state in which people are so involved in an activity that nothing else seems to matter; the experience itself is so enjoyable that people will do it even at greater cost, for the sheer sake of doing it*" [72].

Flow is also considered as an optimal state of intrinsic motivation, where people become absolutely immersed in what they are doing, they forget about physical feelings, passage of time, and their ego fades away [73]. It represents a state in which one feels in control, fully immersed and motivated, at the top of its abilities and neither overwhelmed by difficulty nor uninterested. Csíkszentmihályi states that flow experiences are relatively rare in everyday life, however, various activities are able to produce them, provided certain conditions are met [74]. The activities inducing the state of flow do not have to be of complex nature. That is, the flow can occur during most complex surgical operation or during a simple card game. Kowal and Fortier (1999) have also pointed out that flow can occur in a myriad of life domains, such as work, sports and physical activity, school, and leisure [75]. Csíkszentmihályi further argues that three conditions have to be met in order to achieve a flow state. First, a state of flow needs clearly defined set of goals which must guide the person, and give purpose to the behavior (**clear goals**) [74]. The second condition for obtaining the state of flow is the presence of clear and immediate feedback (**unambiguous feedback**). It informs the person if a specific goal is met and how to adjust performance according to the "*continually changing environment demands*" [74]. Lastly, one of the most important condition is to maintain balance between perceived challenges and perceived skills (**challenge-skill balance**) [74]. When experiencing flow, both the challenge and the skill set, required to meet the challenge, need to be balanced and at an individually high level. Nakamura and Csíkszentmihályi further argue that under these three conditions, individuals can enter a state with the following characteristics [76, 74]:

- **Control**. A sense that one has skills sufficient enough to minimize the possibility of any mistake or error. Hence, one can fully enjoy the current situation because nothing can emerge as a surprise [74]. This sense of control is believed to be one of the important flow antecedents in games [77].
- **Action–awareness merging**. This implies that the flow state is so involving that it affects the individual in a way that the activity performed becomes spontaneous, automatic and natural.
- **Concentration**. While in flow, one experiences intense and focused concentration on what is being done in the present moment. By doing so, one is able to forget all unpleasant things beyond the performed activity since the person is left with no cognitive resources for irrelevant information processing [77].
- **Loss of self-consciousness**. During the flow, the *self* disappears from one's awareness. That is, while thoroughly engrossed with an activity, as in the state of control, few cognitive resources are available for self-scrutiny [77].

- **Distortion of temporal experience**. Typically, the sense of time during the flow experience tends to bear little relation to the actual passage of time. To put it differently, in a state of flow, one feels that time passes faster than normally.
- **Autotelic experience**. Often, this refers to an activity that is performed simply because it is intrinsically rewarding and not with the expectation of some future benefit. It is also referred to as the end result of other conditions and characteristics that induce flow.

Whenever individuals try to reflect on their flow experiences, they tend to mention some and often all of these characteristics. The described conditions and characteristics of flow are known as the "*nine dimensions of the state of flow*", where the first five dimensions can be considered as "*flow antecedents*" and the rest indicators of "*flow experience*" [77]. According to Csíkszentmihályi, flow often tends to occur in situations when we face challenges that match our skills and abilities. That is, it occurs when we perform tasks and activities that are neither too difficult nor too easy with respect to the set of skills we possess, a balance of the relationship between challenge and ability [65, 71, 72]. This balance is referred to as *flow zone*. When the task is too difficult (i.e., the skill cannot meet the challenge), that is when one is above the flow channel, we are likely to experience anxiety. In the opposite case, when the task is slightly too easy and task challenges do not come close to our ability, the result is boredom.

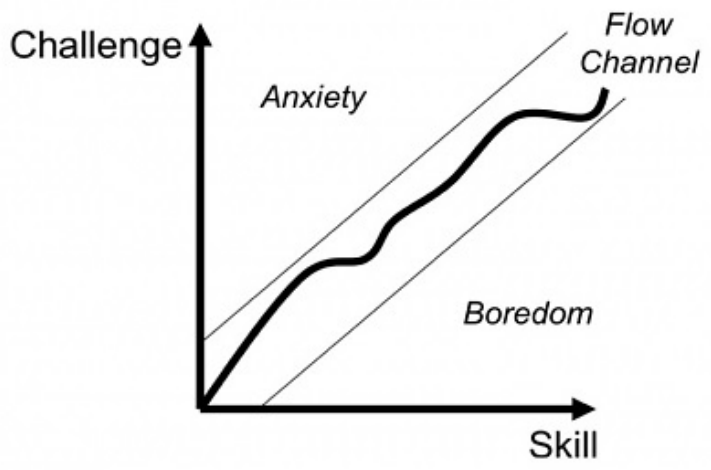

FIGURE 2.10: The flow channel [65]

Figure 2.10 depicts the graphical representation of the state of flow, where y-axis represents the difficulty of the challenge and the x-axis skill set required to meet the specific challenge. The diagram also contains the flow-channel, as well as the anxiety-region and the boredom region. Over the years, new theories regarding the state of flow have been introduced and the concept flow was redefined by introducing eight experimental channels rather than previously mentioned quadrants [76].

Figure 2.11 shows the refined *challenge - skill* space which now contains a series of concentric rings, associated with increasing intensity of experience. Based on the current model of the flow state (Figure 2.11), the flow is experienced in situation when challenges and skills are above the individual's average levels. When the task is slightly too easy (or slightly too hard) we fall out of the state of flow and enter a state where we feel in control (or the state where we feel aroused if the task is slightly too hard). When the difficulty of the task performed is above our skills, we are tend to experience anxiety. On the other hand, if challenges do not come close to our ability, we tend to experience boredom.

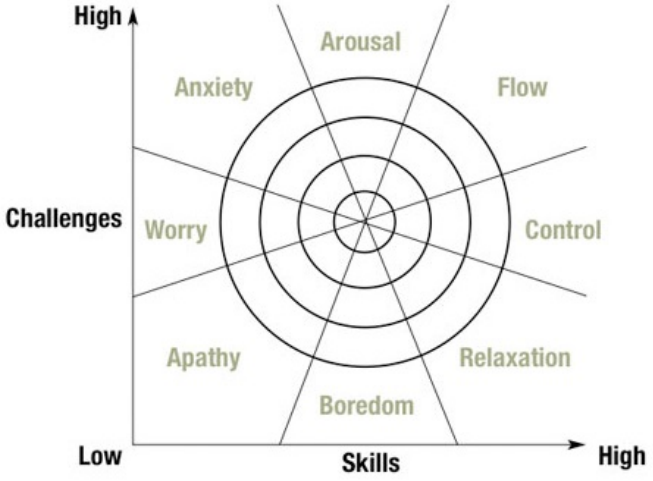

FIGURE 2.11: The current model of the flow state [76]

In cases when the challanges and our skills are at relatively low level, apathy is experienced. The new model also deals with the intensity of the experience. Presented by the concentric rings in Figure 2.11, it can be noticed that the experience level increases with distance from person's average levels of challenge and skill [76]. Csíkszentmihályi also argues how sports and games are more likely to lead to a flow state since they usually have clear goals and feedback structures. However, a given individual can find flow in almost every activity that for some other individuals might seem boring or tiresome [74].

2.3.3.1 Flow, Gamification, and Exergames

In the context related to human behavior and computers, the concept of flow has been mostly studied in video games, human-computer interaction, and instant messaging, to name a few [78]. Currently, there exist only few studies investigating flow in the context of gamification

[78, 79]. Thus, there is insufficient data to draw conclusions as to which of the nine dimensions of flow discussed previously would be most important in the context of gamification. To this end, a study was conducted in which the influence and importance of the different dimensions of flow in gamification is investigated [78]. The data for this study was gathered from users of an exercise gamification service (n = 200). As a measurement instrument for flow, the researcher have been utilized the Dispositional Flow Scale - 2 (DSF-2) model, designed to access flow experiences in physical activity [80]. The results showed that autotelic experience, clear goals, (immediate) feedback, control, and challenge-skill balance were the most salient dimensions of flow in gamification (of exercise). On the other hand, time transformation, merging action-awareness, loss of self-consciousness were the least salient as shown in Figure 2.12.

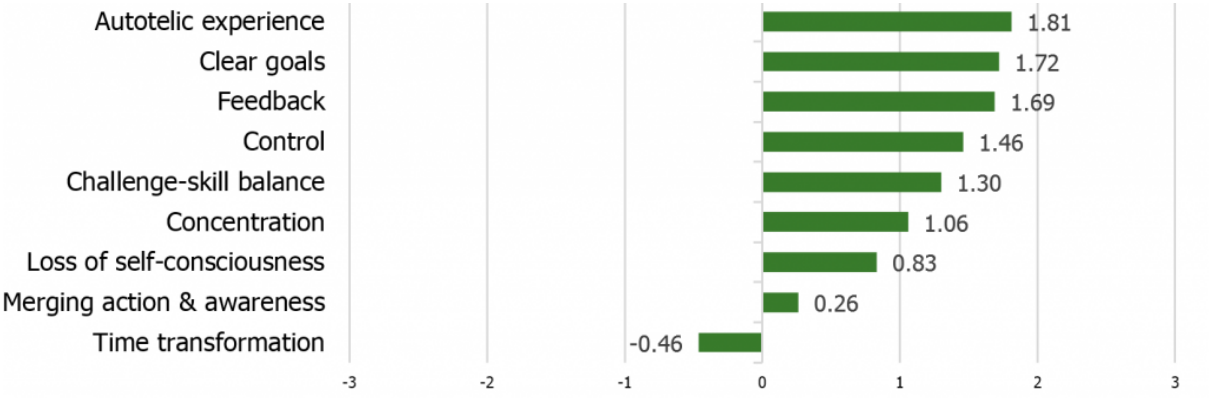

FIGURE 2.12: Measuring flow in Gamification: Dispositional Flow Scale-2 [81].

Furthermore, results also suggest that in gamifed context, the autotelic experience is highly correlated with the conditions. It has also been suggested that in the gamification context, autotelic experience truly represents a condition for reaching flow, thus implying that one can more easily reach flow if the activity is initially intrinsically motivating [78].

Armed with a clearer understanding of the theory behind human motivation, the next chapter provides an overview of the key components of gamification. We place our focus on different player types and how gamification components can influence player's engagement, motivation, and game enjoyment.

Chapter 3

Gamification Elements

An important aspect of game thinking is that players differ from one another and their motivation for engaging in gaming activities should not be generalized. That is, people choose to play games for different reasons, and thus, the same video game can have a different meanings or consequences for different players [82]. The more is known about who is playing the game, the easier it is to design and implement an experience that will drive players' behavior in the desired way [60]. Hence, knowing more about player types and what drives them forward, can help us to design a gamified system that will be utilized more likely by our target audience. The subsequent sections will further explore premises about player behavior and corresponding personality types.

3.1 Bartle's Four Player Types

One way to understand players' motivation is to leverage the work accomplished by Richard Bartle in examining player types. Bartle conducted researches in the area of game design and development, and analyzed the ethnography of online game players in the first Multi-User Dungeon (MUD) in 1978 [83]. In order to understand why people play games, he identified four main player personality types of MUD according to specific psychological aspects of their personality and how they prefer playing in a virtual world: *Explorers*, *Socializers*, *Killers*, and *Achievers* [84]. The player personality types, as depicted in Figure 3.1, can be defined as follows:

- **Explorers** represent players which are driven by motivation to "*find out as much as they can about the virtual world*" [84]. Not only they enjoy exploring every corner of the game environment and searching for interesting features (i.e. bugs), but also understanding how everything functions [84]. In a sense, for this type of players "*the experience is the objective*" [60].

- **Socializers** are player who play games for the benefit of a social interaction [60]. They usually enjoy using communication tools that are provided by the game in order to engage in conversation with other players.
- **Achievers** are goal (achievement) oriented players. They are players who are proud of their "*formal status in the game's built-in level hierarchy*" and also "*of how short a time they took to reach it*" [84]. This type of players are competitive who enjoy beating difficult challenges whether they are explicitly set by the game (e.g. leveling up or gathering points) or by themselves (e.g. accumulating as much virtual money as possible).
- **Killers**, also known as *griefers* [60], are the smallest population of all the player types. They are very similar to achievers in their motivation for winning, however, these players obtain enjoyment from causing anxiety and "*imposing themselves on others*" [84]. For them, winning is only meaningful if someone else loses.

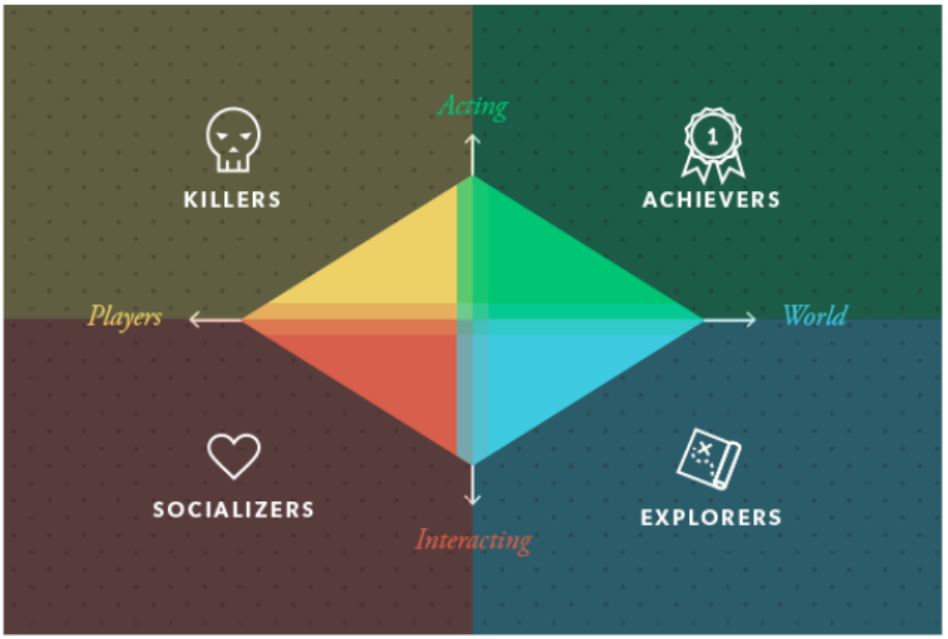

FIGURE 3.1: Bartle's taxonomy of player types [85].

In Figure 3.1, axes represent the source of players' interest in MUD. The horizontal axis depicts the player's preference for interacting with other players vs. interacting with the world. The vertical axis represents the player's preference for (inter)acting with something vs. (inter)acting on something. Thus, according to Figure 3.1, achievers prefer to act on the world, while socializers prefer to interact with other players [85]. It is important to point out that people are not exclusively one or another of the presented player types [60]. Zichermann and Hunter [60] argue that most people have some percentage of each type and the most dominant type will probably change throughout the individual's life.

Even though Bartle's player types have not been designed in particular for gamification it can help in understanding what attitudes may be dealt with when implementing a gamified solution.

3.2 Marczewski's User Types Hexad

Bartle's taxonomy of user types was created specifically for MUD and it should not be generalized to other game genres nor to gameful design [86]. Moreover, it does not consider players who are extrinsically motivated. In order to address these issues Marczewski proposed six user types that differ in the degree to which they can be motivated by either intrinsic or extrinsic motivational factors [86] and introduced the Gamification User Types Hexad that is depicted in Figure 3.2.

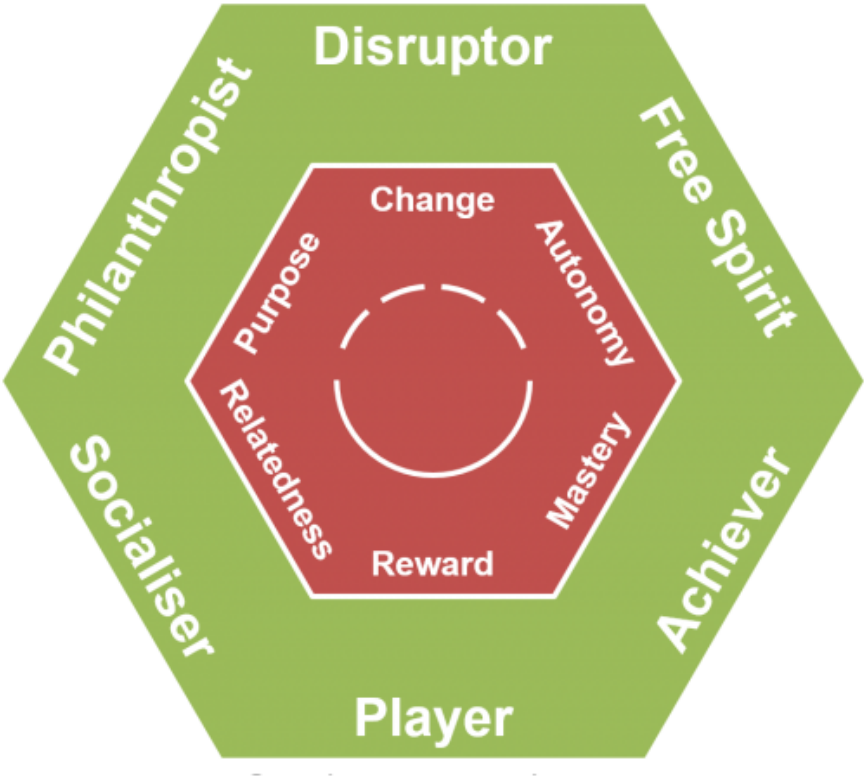

FIGURE 3.2: Gamification user types hexad [86].

The Hexad Model is developed in order to identify the users of the gamified system more efficiently. It is based on users' intrinsic and extrinsic motivations as defined by SDT and enables accurate measures of user preferences [86]. Marczewski identifies the following player types:

- **Socialisers**. Individuals who are motivated by *Relatedness*. They prefer to interact with others players and create social connections with them [86].
- **Free Spirits**. Individuals who are motivated by *Autonomy* and self-expression. They enjoy the freedom of expression and acting without any external control [86].

- **Achievers**. Individuals who are motivated by *Competence*. As in Bartle's taxonomy, this group seek progress withing the gamified environment by completing various tasks and enjoy proving themselves by overcoming difficult challenges [86].
- **Philanthropists**. Individuals who are motivated by *Purpose* and *Meaning*. These individuals enjoy giving to others with no expectation of reward in return [86].
- **Players**. Individuals who are motivated by *Extrinsic rewards*. This player type is motivated only by the reward offered by the gamified system. They will do anything necessary to obtain the extrinsic reward independently of the type of the activity [86].
- **Disruptors**. Individuals who are motivated by *Change*. In general, they tend to disrupt the system either directly or through other users in order to force positive or negative changes [86].

As already mentioned, most people demonstrate each player type to a certain degree. Understanding these player types will support the process of choosing the game elements that will be most appealing for the target audience and drive the desired behavior. Furthermore, adding features and content in order to appeal to different player types can be of great help to diversify the audience of the gamified system, and create enjoyable experiences for many players.

3.2.1 Game design elements

In [60], Zimmerman and Cunningham argue that in order to achieve the greatest impact for players when creating a gamified experience, one should leverage aspects of game design by focusing on its core elements. However, as already pointed out, the goal of gamification is not to build a "full-fledged game", but to use game elements in order to provide a gamified experience and enrich the application to engage and motivate the users [44, 41]. Game design elements are the basic building blocks of gamification applications [44, 41]. With respect to the usage of game elements in gamified system, there have been various attempts to group and classify them based on certain criteria [44, 41, 45, 60]. The most broadly used game elements that are present in most gamified systems are points, badges, and leaderboards. These elements are commonly known as The PBL Triad [41]. Derived from the available literature, [44] found that game elements previously identified and presented in different research studies, fell into five distinct levels of abstraction. Table 3.1 presents a model for classifying game elements. It has five levels of abstraction, ordered from concrete to abstract [44]. On the other hand, [45] does not classify but only lists typical game elements such as goals, time, rules conflict, competition, cooperation, feedback, levels, storytelling, curve of interest, and aesthetics. Likewise, [87] identifies and lists 52 (as of January 2018) elements that support various player types and can enhance gamification designs.

TABLE 3.1: Taxonomy of game design elements by level of abstraction. Adopted from [44]

Level	**Description**	**Example**
Game interface design patterns	Common, successful interaction design components and design solutions for a known problem in a context, including prototypical implementations	Badge, leaderboard, level
Game design patterns and mechanics	Commonly reoccurring parts of the design of a game that concern gameplay	Time constraint, limited resources, turns
Game design principles and heuristics	Evaluative guidelines to approach a design problem or analyze a given design solution	Enduring play, clear goals, variety of game styles
Game models	Conceptual models of the components of games or game experience	MDA; challenge, fantasy, curiosity; game design atoms; Core Elements of the Gaming Experience
Game design methods	Game design-specific practices and processes	Playtesting, playcentric design, value conscious game design

In [60], researchers take a different approach and base their description of game elements on the MDA framework, which is categorized as a *game model* in the framework proposed by [44]. It is one of the most frequently used frameworks of game design and stands for The Mechanics-Dynamics-Aesthetics Framework [88]. Introduced by Robin Hunicke, Mark LeBlanc and Robert Zubek, the MDA framework formalizes games consumption by breaking them into their distinct elements: *rules*, *system*, and *fun*. These elements translate into the following design counterparts which constitute the MDA framework: *Mechanics*, *Dynamics* and *Aesthetics* [88]. Mechanics are the functioning components that make up the game, such as The PBL Triad. They represent the specific elements of the game and control mechanism that are provided to the player within the game's context. Dynamics, on the other side, represents player's interactions with the mechanics. They specify how the player reacts to and interacts with the mechanics of the system, both individually and with other players. Lastly, the aesthetics of the system are the emotional reponses of the users who interact with the game system [60]. This framework has been very influential in helping game designers in conceptualizing different aspects of games.
Another approach in classifying game elements is introduced by Kevin Werbach and Dan Hunter [41]. The authors base their classification of game design elements on the previously introduced MDA framework. They argue that "*game elements exist in a hierarchy*" and establish three categories of game elements that of relevance to gamification.

These categories are: *Dynamics*, *Mechanics*, and *Components*. The terms are similar to the ones presented in the MDA framework, although in [41] are used differently. The gamification elements in decreasing order of abstraction where each mechanic is tied to one or more dynamics, and each component is tied to one or more higher-level elements as depicted in Figure 3.3.

FIGURE 3.3: The Pyramid of Game Elements from Werbach and Hunter [41].

In the next section different gamification mechanics, dynamics and components are listed and described. In order to fulfill their objectives, all elements also need to be analyzed with respect to their impact on player's motivation and previously specified player types. This way, the most appropriate ones can be selected, taking into account the game context, without affecting player's motivation.

Dynamics

At the highest level of abstraction are game dynamics that serve as the core, underlying framework for the gamification to take place. They represent the implicit structure that guides the game, sets up the rules and constraints, and defines the overall purpose, aim and goal of the game and gamified system [41, 89]. According to Werbach and Hunter, the most important game dynamics are [41]:

- **Constraints** (limitations or forced trade-offs). Every game has some constraints, because games create meaningful choices and challenging problems by limiting player's freedom of acting. Hence, the decision of what constraints get put on users represent an important dynamic that game designers needs to take into account.

- **Emotions**. Games can produce a myriad of emotions. However, Werbach argues that the emotional palette of gamification is typically somewhat more limited [89]. The reason for this is because gamification deals with real world, non-game context, such as marketing, health, or exercise context. In cases like those, getting someone, for instance, really upset, will probable not be beneficial and valued.
- **Narrative** (a consistent, ongoing storyline). It represents the structure that pulls together the various elements of the game. In case when in the gamified system exists no sense of narrative, there is a risk that it becomes a bunch of abstract and incoherent concepts randomly tied together. For instance, the player should be well aware of the mechanics behind the scoring system. When they are, the players can easily set their own goals which, in turn, can increase their motivation and engagement.
- **Progression** (the player's growth and development) represent one of the most important dynamics in a gamified system which can stimulate the basic psychological needs like competence and relatedness. The third psychological need (autonomy) can also be stimulated by allowing players to decide the nature of their progress.
- **Relationships** (social interactions generating feelings of camaraderie, status, altruism, to name a few).

Mechanics

Kevin Werbach describes game mechanics as "*the processes that drive actions forward*". He subsequently compared mechanics to "*verbs*" which help people to play games [41]. These are the essential processes that generate player engagement. Werbach identifies ten important game mechanics:

- **Challenges** - puzzles or other tasks that require effort to solve.
- **Chance** - elements of randomness.
- **Competition** - one player or group wins, and the other loses.
- **Cooperation** - players must work together to achieve a shared goal.
- **Feedback** - information about how the player is doing.
- **Resource acquisition** - obtaining useful or collectible items.
- **Rewards** - benefits for some action or achievement.
- **Transactions** - trading between players, directly or through intermediaries.

- **Turns** - sequential participation by alternating players.
- **Win States** - objectives that makes one player or group the winner - draw and loss states are related concepts.

Even though all listed dynamics can potentially enhance users' engagement and motivation for certain activities, to prevent going beyond the scope of this thesis, the listed dynamics will not be further discussed in details.

Components

Components make up the largest fraction of game elements. They can be viewed as more-specific forms that game mechanics or dynamics can take. These elements are less abstract than the categories described previously, and lead to tools that can be used in order to begin incorporating gamification in the context of interest. There exist various game components that can be successfully used in gamified systems. However, some are more common than others, and some are more influential in shaping common examples of gamification. Werbach and Hunter [41] examined over 100 implementations of gamified systems and claim that three elements always appear. These elements are: *points, badges*, and *leaderboards*, commonly reffered to as the PBL Triad. They further point out how these elements are so common within gamification that "*they are often described as though they are gamification*", even though they are not [41]. In their comprehensive survey of peer-reviewed empirical studies on gamification, researchers [40] also found that these three elements "*were clearly the most commonly found variants*" in the large variety of elements tested. The same elements were listed and described by Zichermann, alongside *levels*, *challenges/quests*, *onboarding*, and *engagement loops* [60]. The PBL triad represents a useful starting point for building gamified solution. However, relying only on them can lead to negative outcomes [41]. This is because elements on their own do not make the game [41, 89]. They represent great tools for communicating progress and acknowledging players effort, but neither points nor badges in any way constitute a game. This is where problems usually emanate. Heavily relying only on these elements, without understanding other aspects of game design, could suppress players' intrinsic motivation to engage with a gamified system. However, no actual empirical evidence exists to back this claim [90]. Furthermore, when using the PBL triad, the most emphasis is put on rewards. The problem with this, according to Werbach, is that "*not all rewards are fun; not all fun is rewarding*" [89]. Also, not all player types are motivated by rewards. Thus, relying only on them, might demotivate other player types in further engagement with the gamified system. Werbach claims that the thing that can make game elements successful is the "*way they are all tied together*", which often involves some higher level concepts such as dynamics. To sum up, even though PBLs have huge potential, they are not right for every project.

That is why, some other elements should also be considered in order to "*extract the maximum value from gamification*" [41]. Apart from the described ones, Werbach and Zichermann also identified various gamification mechanics that can be used in gamified systems. Some of the most common are [60]:

- Achievements - defined objectives.
- Avatars - visual representations of a player's character.
- Collections - sets of items or badges to accumulate.
- Combat - a defined battle, typically short-lived.
- Content unlocking - aspects available only when players reach objectives.
- Gifting - opportunities to share resources with others.
- Levels - defined steps in player progression.
- Quests - predefined challenges with objectives and rewards.
- Social graphs - representation of players' social network within the game.
- Teams - defined groups of players working together for a common goal.
- Virtual goods - game assets with perceived or real-money value.

According to Werbach the central task of gamification design is putting all these elements together. However, one should keep in mind that no gamification system will or need to include all of these elements. On the other hand, it is necessary to take into account all the possible elements in order to build an engaging gamified service [41].

In the following chapters we detail the development process of our gamified system and further discuss the reasoning behind gamification elements that were incorporated.

Chapter 4

The Design and Development of the Immotion Exergame

This chapter outlines the design and development of the Immotion exergame for warm up routine guidance and motivation. We begin this chapter with the description of the design methodology used for the development. For the purpose of this thesis, an iterative and prototype driven, user centred design methodology was adopted. After the methodology has been introduced, we continue with the in depth discussion of each individual development phase. Our main focus is placed on the last two stages of the development process in which we develop the prototype and the final version of our exergame solution, and evaluate them utilizing various qualitative and quantitative evaluation methods. During all the development phases, the particular needs of individuals who engage in physical (sports) activities but rarely or never warm up prior to them have been taken into account and gathered through the adopted design process in order to make an adequate exergame for warm up guidance and motivation.

4.1 Overview of User Centered Design

User Centered Design (UCD) represents *a user interface design process* that puts its focus on usability goals, explicit understanding of users, environment, and tasks to be performed [91]. Moreover, it is an iterative process, where design and evaluation phases are included from the first stage of the development, that addresses the whole user experience, and is driven and refined by user-centered evaluation. Adopted from [92], the following are the general and advised phases of the UCD process:

- *Specify the context of use.* Identify future users of the solution, the intended purpose of usage, and the conditions under which the solution will be used.

- *Specify requirements.* Identify user goals that must be met in order for the solution success.
- *Create design solutions.* Done in stages, building from a rough concept to a complete and final design.
- *Evaluate designs.* Evaluation should be performed through usability testing with actual users.

Even though being a relatively new field, exergame developers often indicate the relevance of including the players in the design process and point out the benefits of adopting UCD in exergames development. In their study on exergame design for elderly users, Gerling and Masuch recommend and utilize UCD for developing exergames for an elderly audience [55]. Researchers in [93] also take advantage of UCD in their year long study whilst developing action-oriented exergames for children with cerebral palsy. As showed that UCD can be used for designing effective exergames for specific target demographic, we also adopt this approach in the development of our exergame solution.

4.2 The Context of Use

There exist commercial and non-commercial exergame solutions designed to encourage physical activity. These solutions are mainly intended to be used for home and in-door workout activities. Many of them offer multitudes of predefined exercise programs and also make it easy to create a fully customized workout plan that are suited for individual's needs and abilities. However, in our research, we found no available solutions that focus solely on the warm up routine as a preparatory activity before physically more demanding exercise. Taking this into account, as well as the fact that warm up routines are crucial part of any sports activity [11, 13] although often avoided by multitude of athletes [19], with the Immotion exergame we chose to tackle exactly this issue. We design and develop our exergame to be used as a warm up guidance and motivation tool. That is, our exergame is intended to be used in gyms and fitness centres before any arduous sports activity. Additionally, we target individuals, above all amateur athletes, who often avoid or do not know how to perform a proper warm up routine. Lastly, we design our exergame so the movements required to be executed are intuitive for the player and do not require additional explanation nor previous exercise knowledge.

4.3 Overview of the Development Phases

The development of the Immotion exergame consisted of three phases which are according to the well accepted UCD development phases outlined in the previous section and depicted in Figure 4.1:

- Requirements gathering
- First prototype development with user evaluation
- Final exergame development with further user evaluation

In the following sections, each iteration presented in *Development* slice and the *Requirement Gathering* iteration of the *Planning* slice depicted in Figure 4.1 will be further detailed.

FIGURE 4.1: Overview of the development iterations

4.4 Requirements Gathering

This iteration was an exploratory step that justified the development and identified the currently available solutions in the domain of exergames for warm up before sports activities. This was achieved through initial literature review related to exergame, gamification, and motivational psychology which identified the most important areas to be addressed when developing gamified solution in the given context. Furthermore, in order to design an enjoyable exergame solution, several warm up and sports related requirements needed to be considered too. Having this in mind, sports and fitness related literature have been reviewed as well. Particular attention has been put on those warm up exercises that could hypothetically help in injury prevention and improve performance. Our exergame is meant to be used in gym or fitness centers before physically demanding sports activities. Hence, the movements required in the game should be those that increase core body temperature, blood flow, and prepare the body for the subsequent exercise. In addition, we had to take into account certain constraints and requirements when selecting these movements. Some of the them were as follows:

- Movements needed to be easily detectable by only one Kinect device.
- Movements should be easy enough to be correctly performed without any prior knowledge of the movement or exercise.
- Only movements that can be executed without additional equipment should be considered.
- Only movements recommended for the general warm up routines outlined in sports related literature and suggested by experts should be considered.
- The duration of the exergame guided warm up routine should correspond to the warm up duration suggested by sports literature and experts.

Since no well documented and medically supported warm up programmes for workout routines were found, the required movements were adopted from the FIFA 11+ Warm Up Program (FIFA 11+) [23] warm up programme which mostly focuses on core and leg strength, balance, and agility. These programmes were shown to have significant impact on injury reduction in football players and can lead to improvements in thigh muscle strength, jump height, and sprint speed [94]. Based on the mentioned warm up programs review, the previously listed requirements, and hardware restrictions outlined, the following movements were found to be suitable for the prototype solution: *jump right*, *jump left*, *jump up*, and *squat*.
After the requirements were specified and the required movements selected, we continued with the prototype development phase.

Chapter 5

Overview and Evaluation of the Prototype Exergame

5.1 Prototype Design and Development

This section outlines the development of the prototype version of the exergame for warm up guidance and motivation before sports activities. Our primary goal was to develop a working version of the exergame that can process movements in real time in order to guide users through the warm up routine and, presumably, immerses the participants sufficiently so that their focus is shifted from the discomfort and exertion of the exercise towards the enjoyment of the experience. The prototype was developed as a scaled down version of our planned final solution. With the prototype, we aimed to learn more about the problem, possible target groups, and explore the most suitable design and implementation techniques that could be used during the exergame development process.

5.1.1 Game Description

The Immotion exergame was created using Unity 5.6 game development platform developed by Unity Technologies. Players' movements were captured and processed with Kinect for Xbox One (2.0 2013) motion sensing input devices by Microsoft. The game engine was run on a PC running Windows 10 OS, and projected on a wall using a projector.
For the prototype version of the exergame, a game scenario that is similar to *Subway Surfers* and *Temple Run* games was implemented. In these games, the player controls the character that is on a track and needs to move left, right or jump up in order to avoid obstacles and collect points. In our solution, the player controlled the character by doing a set of movements, which were tracked in real time with a Microsoft Kinect device.

In-game obstacles (e.i. walls or boxes) and coins were positioned in a way that the player was required to perform a specific movement in order to avoid the obstacle or collect a coin. By collecting coins the overall player's score was increased. Contrarily, by hitting an obstacle, the overall player's score was decreased. By placing the obstacle and coins in a specific position, our intention was to indirectly promote exercise through the gameplay of repeatedly performing warm up related movements chosen during previous development phases. Figure 5.1 depicts the usage of the prototype version of the Immotion exergame during one of our final tests.

FIGURE 5.1: Interacting with the prototype version of the Immotion exergame

Next, the main gamification elements that are incorporated into our exergame are further discussed.

5.1.2 Gamification Elements used in the Prototype

In order to create an immersive game environment that will shift users' focus from the exertion of the exercise, we also employed few game *mechanics*. Werbach and Hunter report that mechanics provide the "*basic processes that drive the action forward and generate player engagement*" [41]. For the prototype version of the Immotion exergame, the most important mechanics was *Feedback*.

Feedback

As pointed out in Chapter 2, feedback have been shown to influence and improve autonomy and, hence, the intrinsic motivation of individuals. Warbach and Hunter argue that giving unanticipated, informal feedback or support about the player's progress can provoke increased intrinsic motivation and autonomy [41]. They further outline that gamification components represent specific examples and ways for doing the higher level things that gamification mechanics and dynamics represent. In the prototype version of the exergame, the player received feedback using different gamification components that will be further detailed.

5.1.3 Gamification Components used in the Prototype

Points

According to Zichermann and Cunningham [60] points are "*an absolute requirement for all gamified systems*", because they can serve a wide range of purposes. One of the most obvious is for keeping a score and evaluate progress of the user. However, they can serve as a powerful extrinsic motivator for player types that enjoy collecting points, like *Killers* or *Achievers*. In the prototype version of the exergame, the player could earn points by collecting coins and lose them by hitting an obstacle. How much points could the player earn or lose by each action is presented in Figure 5.2.

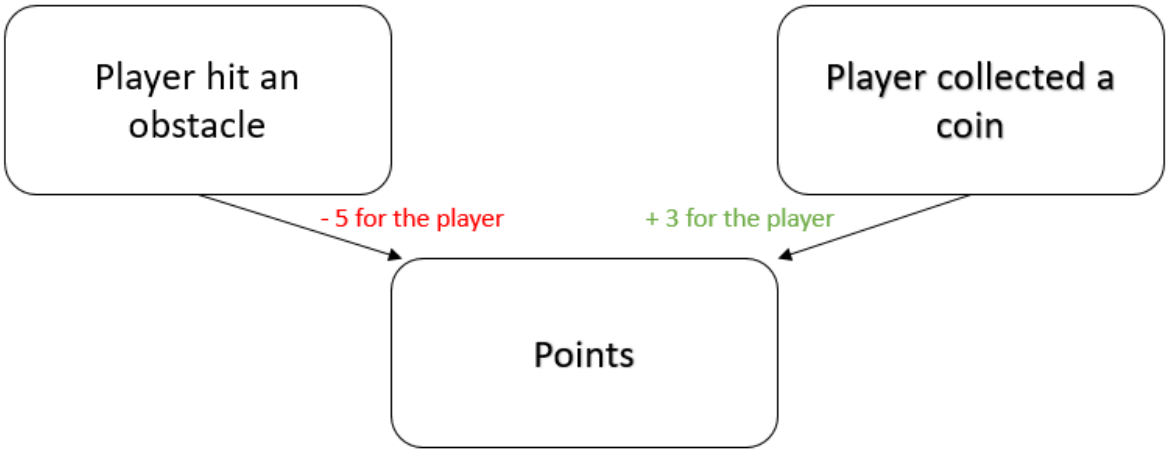

FIGURE 5.2: Earning and loosing point in the prototype version of the exergame

As per Figure 5.2, the player could earn 3 points by collecting a coin. Contrarily, the player could lose 5 points if hit by an obstacle. In order to avoid hitting an obstacle or collect a coin, a movement was required to be performed by the player.

Consequentially, the player was guided through the warm up routine without even realizing it. In the course of the game, the player's current score was displayed in the right corner. That way, the player had constant overview of her progress.

Avatar

In the prototype version of the game we used a simplistic avatar which players controlled by performing the movements in front of the Kinect sensor. The main purpose of the avatar was to correctly replicate player's movements. By doing so, the player got a real time feedback on how the movement was performed. The avatar that was utilized for the prototype version is presented in Figure 5.3.

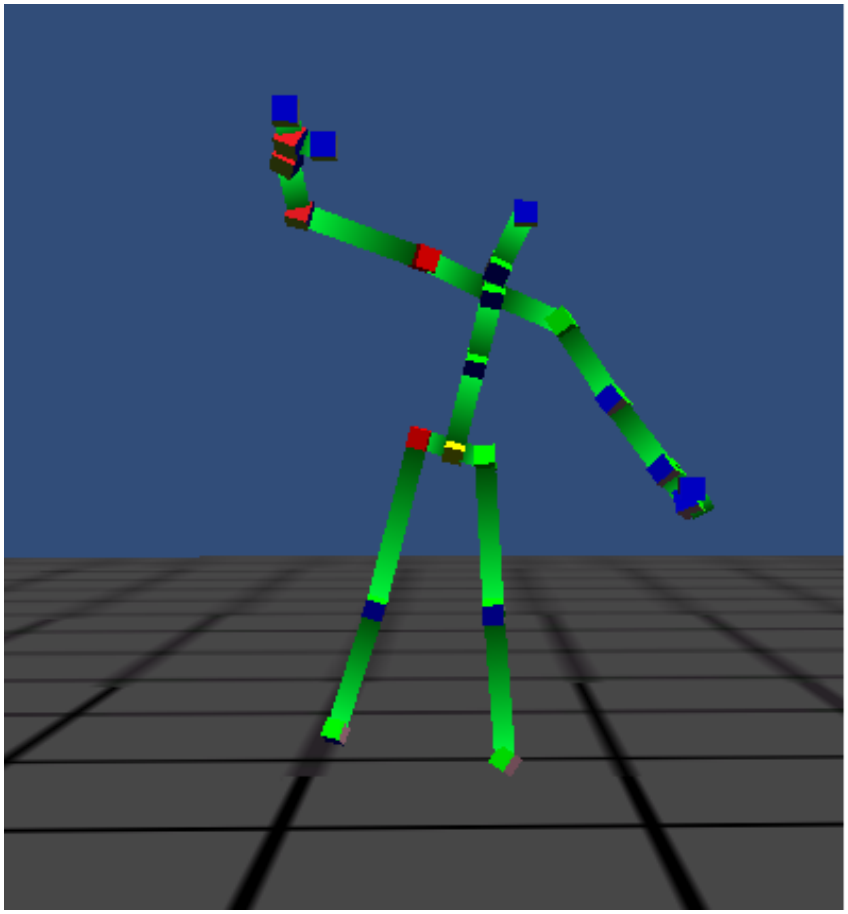

FIGURE 5.3: The avatar used in the prototype game.

Visual Feedback

Even though cannot be counted among gamification components, for the purpose of giving players the necessary feedback, we introduced additional visual components. The player was informed when a game obstacle was hit by the avatar. This was done by adding red overlay to the scene every time event of this kind occurred. This informed the player that the last movement was not successful, and deducted points from player's overall score.

Audio Feedback

Similarly to previous component, audio cues were introduced to inform the player of success or failure of the performed movement. In case the player managed to collect a coin successfully, a sound comparable to the one heard when collecting a coin in many video games is played. Contrarily, a crashing sound was played on failure when the player hit an obstacle. The volume of the sounds played on success or failure were balanced as much as possible so that they were distinct enough but not disturbing to the player of the exergame.

5.1.4 Game Scenes

Figure 5.4 shows the scenes from the prototype version of the exergame. Only one scene was designed and implemented for our prototype solution.

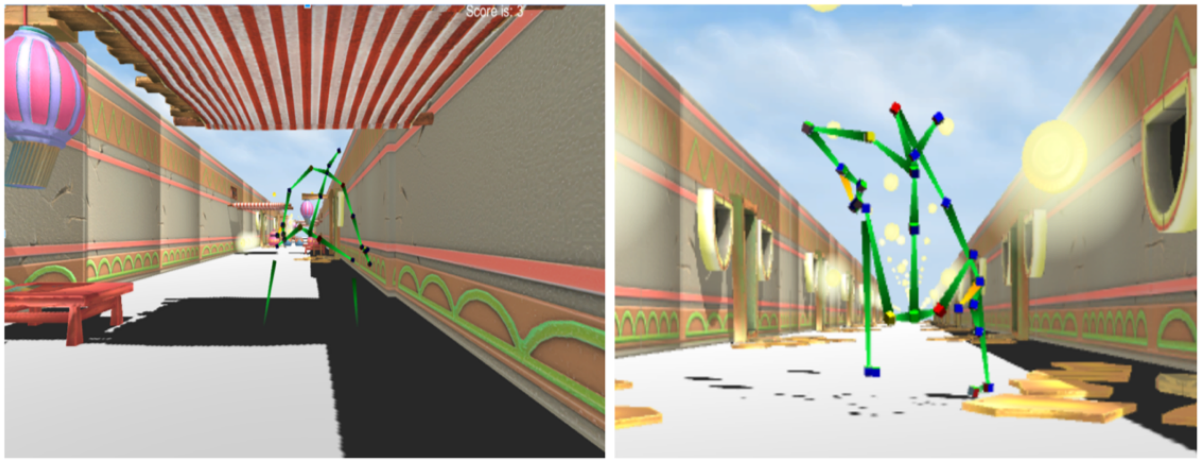

FIGURE 5.4: Game scenes from the prototype version of the exergame

5.2 Prototype Evaluation

The goal of this section is to document and describe the evaluation process of the Immotion warm up exergame in this thesis. The process was separated into three stages. In the first stage we assess the prototype of our gamified system and its elements. Through a survey we evaluated which features of the gamified system were appreciated the most and which the least, and hence could be removed or improved. In the second stage, based on the feedback and reactions received from the respondents in the first stage, we completed the implementation of the second release of our gamified system. In the last stage, we pilot-tested our gamified system at the University with few student volunteers. In order to measure overall acceptance of our gamified solution for warm up, different methods have been used which will be described in the following sections. The data is visualized using *Tableau Desktop 10.3* software. The results from this evaluation should help to answer the overall research questions of this thesis:

1. *Can exergames with gamification elements make warm up routines more enjoyable and, thus, motivate individuals to warm up more regularly before physically more demanding exercises?*
2. *Can exergames with gamification elements be used as a interactive guidance for individuals who do not know how to perform warm up routines before physically more demanding exercises?*

5.3 Quantitative Methods

To gain a first insight into acceptance of the Immotion warm up game we created an online survey. The survey was created using *Google forms* and was accessible for two weeks from 16th to 30th of July 2017. The survey has been advertised via social networking services (*Facebook* and *LinkedIn*) and e-mail lists. No incentives were used to collect responds for this survey. Since our gamified system ought to be used before physically more demanding exercise (training) in gyms, fitness and sports centres, we targeted individuals who are physically active and engage in some sort of physical (sport) activity on a regular or semi-regular basis. The goal of this survey was to explore general work out and warm up habits of the respondents and their preferences, as well as the general acceptance of a gamified solution of a warm up routine. The questions in the survey were divided into three parts. First, the participants were asked a set of general questions regarding their age, gender and education level. Next, their training habits and warm up preferences were assessed. Lastly, participants were showed a video of the prototype version of the warm up game and asked questions related to the presented gamified solution for warm up guidance.

5.3.1 General Questions

In the first part of the survey, the respondents are asked general questions about their gender, age and education level. Total number of n = 446 individuals participated in the survey, of which n = 204 (45.7%) were female and n = 242 (54.3%) male. The age of the respondents ranged from 17 to 58 with an average age of 30.16 years (SD = 6.49). Regarding participants' education level, the majority of the respondents completed either their Master's studies n = 209 (46.9%) or Bachelor studies n = 151 (33.9%).

5.3.2 Questions Related to Work Out and Warm Up Preferences

The second section of the survey evaluated the respondents work out and warm up preferences. Total number of n = 442 of the respondents were amateur (recreational) athletes (99.1%), while only n = 4 individuals declared themselves as being a professional athlete. In the survey, the respondents were pointed out that the most basic difference between amateur and professional athletes lies in the rewards that each group receives for athletic performances. Generally speaking, amateur athletes are not paid for their athletics performances. Professional athletes, by contrast, are typically paid annual salaries plus incentives tied to individual and team performance [95]. More than half of the respondents (n = 357) reported taking part in some sort of sports activities during the whole year (77.4%), while n = 101 (22.6%) only few months per year. This means that most of the respondents engage in physical activities regularly without any longer stoppage. Regarding weekly training session occurrences, n = 152 respondents reported having 1 to 2 (34.1%) and n = 168 having 3 to 4 (37.7%) work out or sports sessions per week, while n = 54 (12.1%) respondents reported taking part in sports activities irregularly (less than once per week). Most of the respondents (n = 285) reported having training sessions which last between 1 and 2 hours (63.9%). The second most prominent training session duration reported by n = 125 respondents was less than an hour (28%). Only n = 35 respondents reported having sport session with duration more than 3 hours. In Figure 5.5, the pie chart on the left shows the percentage of respondents based on the number of training sessions per week. The pie chart on the right shows the percentage of respondents based on the duration of their training session. Moreover, n = 251 respondents stated that they prefer exercising alone (56.3%), n = 86 (19.3%) with a friend (or friends) and n = 109 in a group (24.4%). Having a personal trainer was not prevalent among the respondents, and only n = 52 reported exercising with a personal trainer. When asked about their warm up preferences before a physical activity, n = 251 respondents (56.3%) reported always warming up before physically more demanding exercises (or sports activities), whereas n = 195 (43.7%) reported not warming up regularly before physically more demanding exercises (or sports activities).

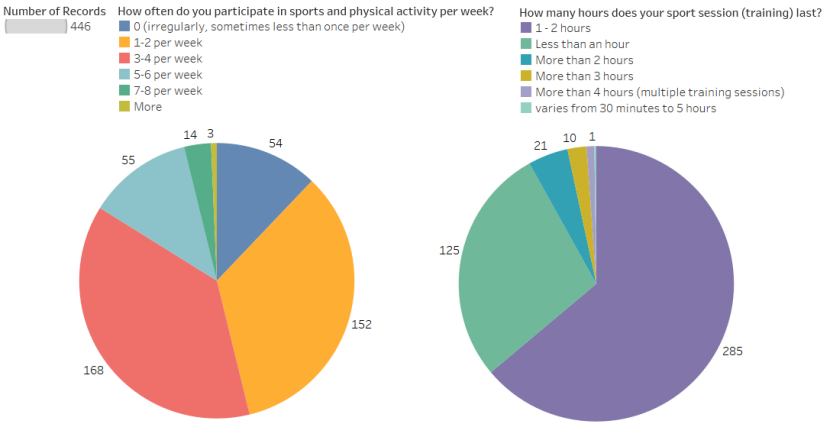

FIGURE 5.5: Respondents' weekly training session number and training duration

These results additionally confirm our assumption regarding absence of warm up habits in multitude of athletes.

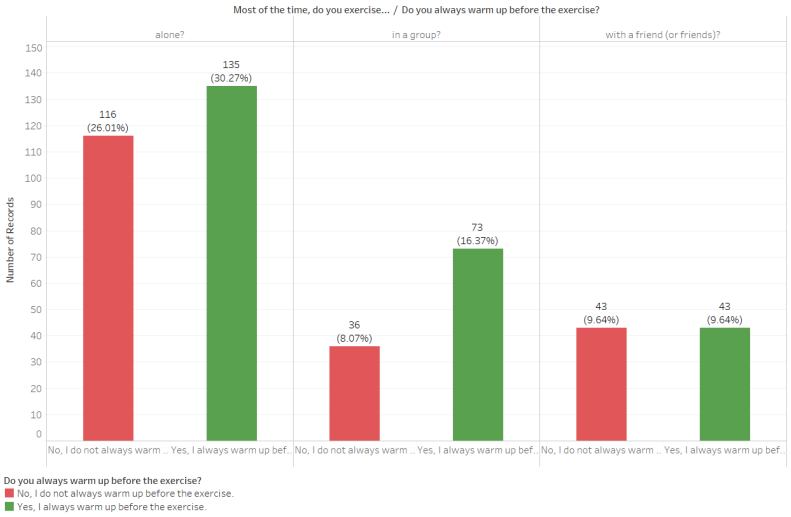

FIGURE 5.6: Sum of Number of Records for the question "*Do you always warm up before the exercise?*" broken down by "*Most of the time, do you exercise alone/with a friend/in a group?*" Color shows details about "*Do you always warm up before the exercise?*"

In Figure 5.6, we represent the respondents' warm up habits with regard their preferences to exercise alone, in a group or with a friend. It is interesting to notice that the most number of respondents who stated not warming up regularly, reported preferring exercise sessions that are carried out alone. On the other hand, we notice that most individuals who reported exercising in a group, regularly warm up before some sports activity. Based on their answer regarding warm up preferences, respondents were further asked different set of questions. Respondents that have stated not warming regularly, have been asked about reasons for not doing so. On the other hand, respondents who reported warming up regularly have been inquired about the duration and types of warm up exercises they usually engage in.

5.3.3 Questions Related to Warm Up Routines

The pie chart in Figure 5.7 shows the number of respondents based on the duration of their warm up sessions before physically more demanding exercise. Only those respondents who reported warming up regularly were asked this question. Among n = 251 respondents that reported always warming up before the training session, the most common duration was between 5 and 10 minutes (43.4%). Next, n = 66 (26.3%) reported warming up less than 5 minutes, n = 64 respondents (25.5%) between 5 and 10 minutes and, lastly n =11 (4.4%) reported warming up more than 15 minutes. Only one respondent reported warming up less than a minute. The answers related to warm up duration gathered from respondents gave us valuable information about the most prevailing duration of warm up sessions. By knowing this, we can limit the duration of our warm up game to correspond to the periods outlined by the respondents through the survey.

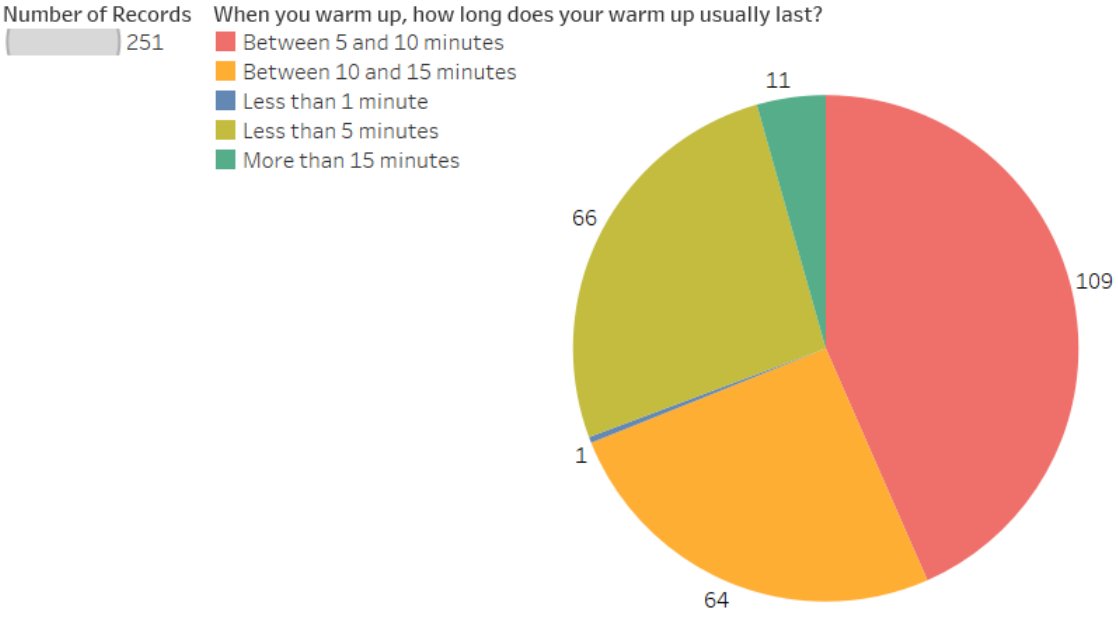

FIGURE 5.7: Responds to the question "*When you warm up, how long does your warm up usually last?*"

When the reported duration of the training session and warm up are compared among the respondents who stated warming up before the physically more demanding exercise, it is evident that the most common warm up duration is between 5 and 10 minutes regardless of the training session duration. In case of training sessions with duration less than 1 hour, the second most common warm up duration is the one that is less than 5 minutes long. On the other hand, in case of training sessions with duration between 1 and 2 hours, the second most common warm up duration is between 10 and 15 minutes.

The highest number of respondents who stated warming up between 10 and 15 minutes belong to the group with the training session duration between 1 and 2 hours. In this group, less than 5 minutes warm up sessions were also customary. Overall, we can conclude that individuals do not tend to spend less than 1 and more than 15 minutes on the warming up procedure before physically more demanding exercises. The results are shown in Figure 5.8.
Taking this into account, the second release of the Immotion warm up game will enable players to choose the warm up duration they prefer the most. The available duration to choose from will be 1 minute, 2 minutes, 3 minutes, 5 minutes, 7 minutes, 10 minutes and 15 minutes which aligns to the duration pointed out by the respondents. These durations align also with the most common ones outlined in Chapter 2 and suggested by different sources [12]. Respondents who reported warming up regularly were also inquired about the type of the warm up exercises they perform before the sport activity. Respondents could choose among three warm up types most often referred to in sports literature [13, 12], which were:

- general warm up,
- sport specific warm up (warm up that reflects the type of movements and actions which will be required during the sporting event), and
- passive warm up (e.g., taking a hot shower, having a rubdown, sitting in the sun)

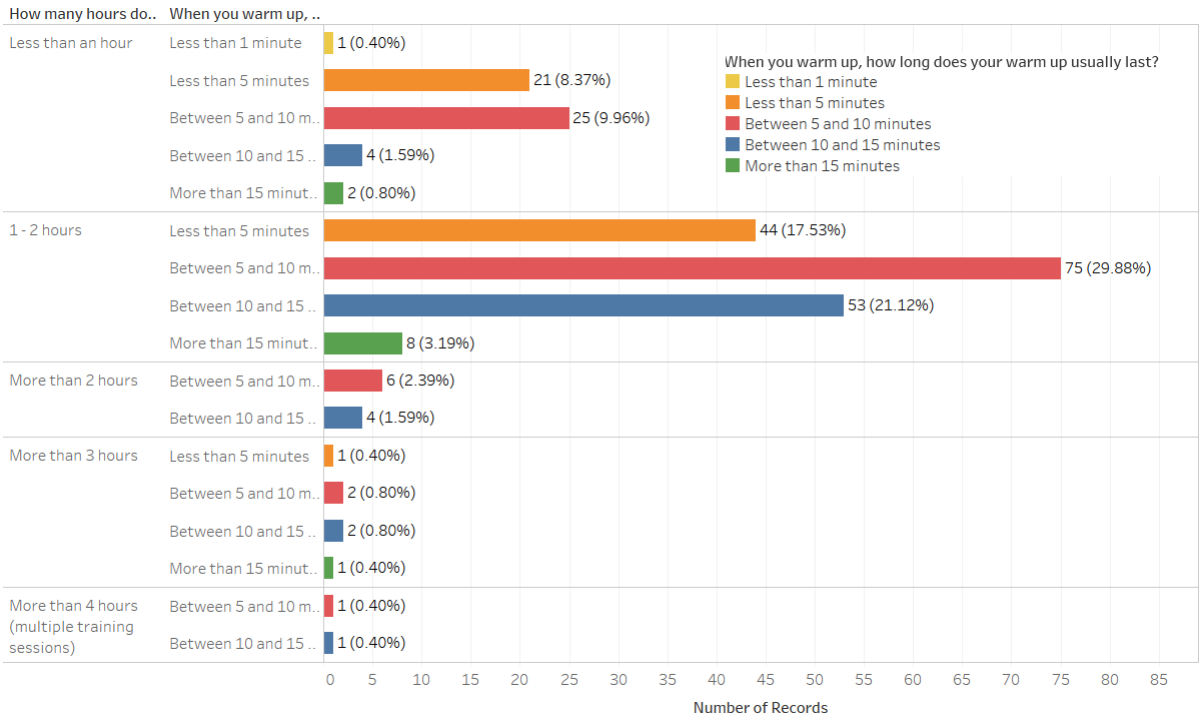

FIGURE 5.8: Sum of Number of Records for each "*How many hours does your sport session (training) last?*". Color shows details about "*When you warm up, how long does your warm up usually last?*"

As mentioned, this question was asked only from those respondents that reported always warming up before the sport activity (n = 251). The most common warm up routine, reported by n = 140 respondents (55.8%), was the sport specific type while the general (non-specific) warm up type was reported by n = 111 (44.2%) of them. None of the respondents reported performing passive warm up before the more demanding physical activity. While using the Immotion warm up game, the player is asked to perform a set of general warm up exercises in order to complete the game. Hence, it was necessary investigate athletes preferences towards types of warm up routines they engage in most often. More than half of the respondents (55.8%) reported engaging in sport specific warm up routine. This indicates that the respondents are more inclined towards specialized and personalized warm up routines, as opposed to the ones required in the prototype warm up game. Thus, the game should support players in selecting the set of warm up routines that are less general and more sport specific based on the sport they want to play (or group of muscles they want to warm up) or diversify and increase the types of movements the player needs to perform in order to successfully finish the game. Furthermore, n = 140 (55.8%) respondents out of n = 251 reported having no inclination towards warming up in a group. Also, n = 101 (40.24%) respondents stated not following any warm up procedure. Next, when asked about their preferences towards warming up when given instructions, n = 156 (61.4%) out of n = 251 reported favoring warm up sessions when they are instructed and demonstrated by someone else. This is a valuable information because it suggests that individuals could, presumably, be inclined to warm up more regularly if they had a guidance through the warm up routine.
With the Immotion game, we tackle exactly this requirement. By placing the obstacles that are to be avoided and coins to be collected, the athlete is instructed and guided through the warm up routine from the moment the game begins. The Immotion warm up game is designed and implemented as a single player game that guides the players through the warming up process and instructs them to perform specific movements in order to finish the game successfully and, consequently, warm up major muscle groups. Hence, it was required to assess these warm up preferences. In addition, out of n = 251 respondents, n = 111 (44.2%) reported enjoying warm up sessions when they are carried out in a group. This leads us to believe that multiplayer (group) warm up should also be an option in the Immotion warm up game. That way, both athlete types (the ones preferring warming up individually and the ones not) can utilize and benefit from the game. Lastly, n = 150 respondents (59.76%) stated following some warm up procedure. This result was unanticipated. However, it suggests that most of the athletes who took the survey and do warm up regularly, are well aware of the beneficial effects of warm up routines, and by following well established and accepted ones, are trying to maximize its positive outcomes. In 5.9, the pie chart on the left shows the percentage of respondents who prefer warming up when given instructions, the pie chart in the middle shows the percentage of respondents who follow some recommended warm up procedure in a group and those who do not and, lastly, the pie chart on the right shows the percentage of respondents who prefer warming up in a group.

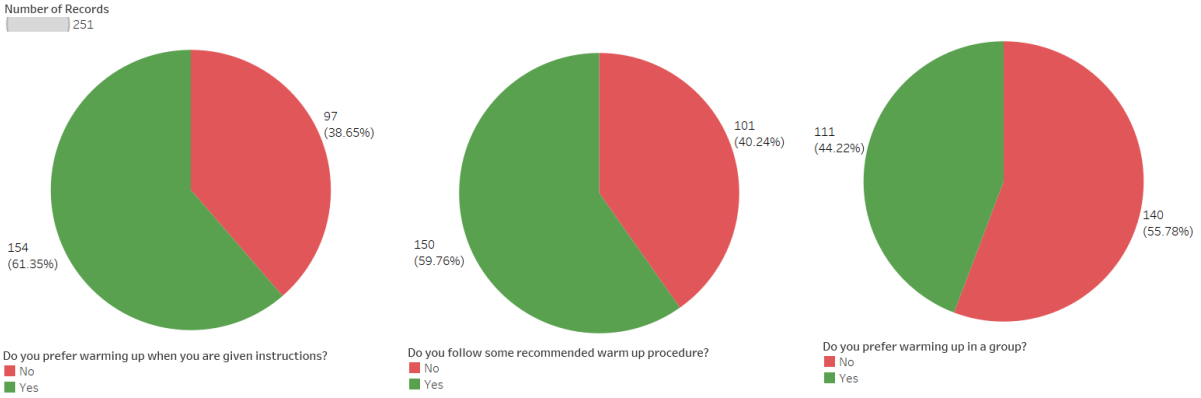

FIGURE 5.9: Respondents' answers for questions "*Do you prefer warming up when you are given instructions*", "*Do you follow some recommended warm up procedure*", "*Do you prefer warming up in a group*"

The pie chart in Figure 5.10 shows the number and percentage of respondents based on their answer on the question "*How were you introduced or recommended to the warm up procedure?*". Answering this question was optional, and it was asked only from those respondents who reported warming up regularly. Among n = 150 respondents that gave answer to this question, n = 81 (54%) stated that they were introduced to the warm up procedure they perform by their coach, n = 27 (18%) have seen the procedure online, while n = 13 (8.67%) have read about it. The rest of the respondents reported seeing others do similar movements before the sports activity (n = 4) and to be introduced to the warm up procedure by their friend (n = 9). Some of the other sources, reported by n = 16 respondents were:

- "*I am a certified personal trainer, so I've adapted my learning to my own training*"
- "*Exercise APPs*"
- "*Physio + Personal trainers + coaches + YouTube channels*"
- "*Studied as part of college course*"

To assess respondents' attitude towards the importance of the warm up procedure before physically more demanding exercise, the respondents (n = 251) were asked to give their preferences regarding the following statements:

- "*Warm up before exercise is important for me.*"
- "*Warm up before exercise can positively affect my performance.*"
- "*Warm up before exercise can reduce the likelihood of an injury.*"
- "*After my warm up routine, I feel prepared for the physically more demanding activity.*"

For each question, respondents could choose among five categories: *Strongly Disagree*, *Disagree*, *Neutral*, *Agree* and *Strongly agree*. Each category is assigned a score from 1 (Strongly Disagree) to 5 (Strongly Agree).

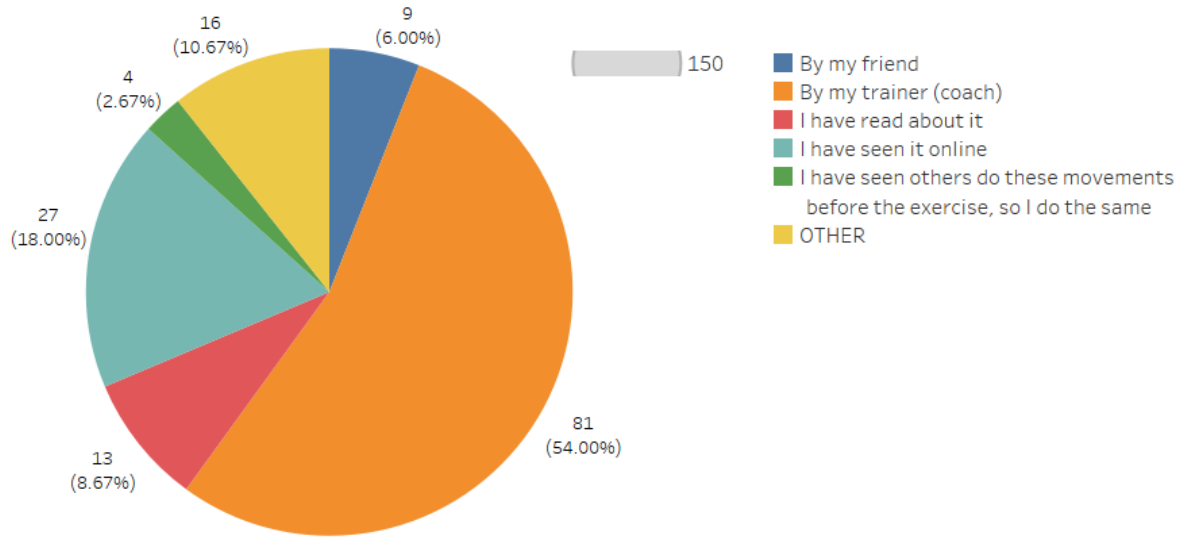

FIGURE 5.10: Sum of Number of Records and Percentage of Total Number of Records for the question "*How were you introduced or recommended to the warm up procedure?*"

In 5.11 we show the *Likert* scale score for the previous statements broken down by respondents' gender. For each question we assign a range of values that show how the survey responses are spread by category and a general feeling whether they are positive or negative. Based on the available categories and their total scores, we specify the dividing line and check how many responses are below and above it. That is, the dividing line is at 0% and the responses left from it are generally negative, and right from it generally positive. Each individual line shows a different starting point for each answer. The offset (lines' starting point) depends on the total number of negative scores, which are in our case the number of Neutral, Disagree and Strongly Disagree divided by the overall score for that question. The overall score (or the number of responses) for all the question is the same, since these questions were mandatory and all respondents answered it. Also, we split the Neutral answers and assign half of it to positive, and half to negative answers so we are not weighting unfairly one side to the other. The width of each individual category depends on the number of records that are in that category over the total number of responses for the entire bar (that particular question). Lastly, we add the overall Likert scale score depicted as a yellow circle in each bar which shows the summary for each individual question. From the responses that are presented in 5.11, we conclude that the respondents have a generally positive stand towards the statements given, since every question has an overall Likert score above 4 out of maximum 5. This positive bias was somewhat expected since the question was asked only from those who reported warming up regularly before sports activities.

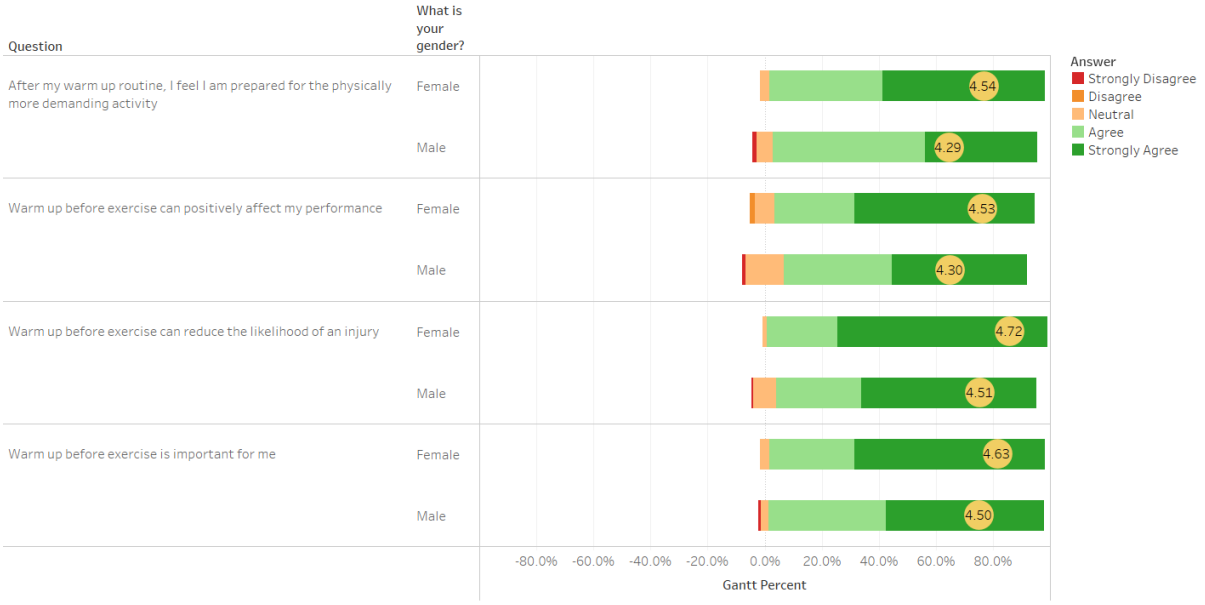

FIGURE 5.11: Gantt Percentage and the average score for the following statements: "*Warm up before exercise is important for me.*", "*Warm up before exercise can positively affect my performance.*", "*Warm up before exercise can reduce the likelihood of an injury.*", "*After my warm up routine, I feel I am prepared for the physically more demanding activity broken down by respondents gender.*"

Some lower scores were obtained for male respondents in the first two statements "*After my warm up routine, I feel I am prepared for the physically more demanding activity*" (4.29) and "*Warm up before exercise can positively affect my performance*" (4.30) which might indicate that a number of the respondents, even though warming up regularly, do not perform the warm up procedure thoroughly and thus, do not feel fully prepared for the subsequent sports activity. Respondents who stated warming up regularly were asked to describe their warm up routine or to list the most common exercises they perform in order to prepare for the physically more demanding ones. Since n = 150 respondents (59.76%) stated following some specific and well established warm up routines, we were interested in the most common movements and exercises these routines combine. Our primary goal was to use those movements and exercises in the game as movements for avoiding obstacles and collecting points. We grouped the answers based on textual occurrences of specific keywords and on textual occurrences of keywords with the same semantic meaning. From the aggregated answers shown in Figure 5.12, we observe that the most of the respondents include stretching exercises in their warm up routine. This was expected since, when asked if they include stretching in their warm up procedure, out of n = 251 respondents, n = 205 reported performing, while n = 46 reported not performing stretching exercises during warm up session. We hypothesize that the reasons for this is that athletes confuse stretching with warming up and believe stretching exercises can prepare our body for strenuous activity as well as prevent injuries. However, as already pointed out in Chapter 2, there exists no scientific evidence for these assumptions.

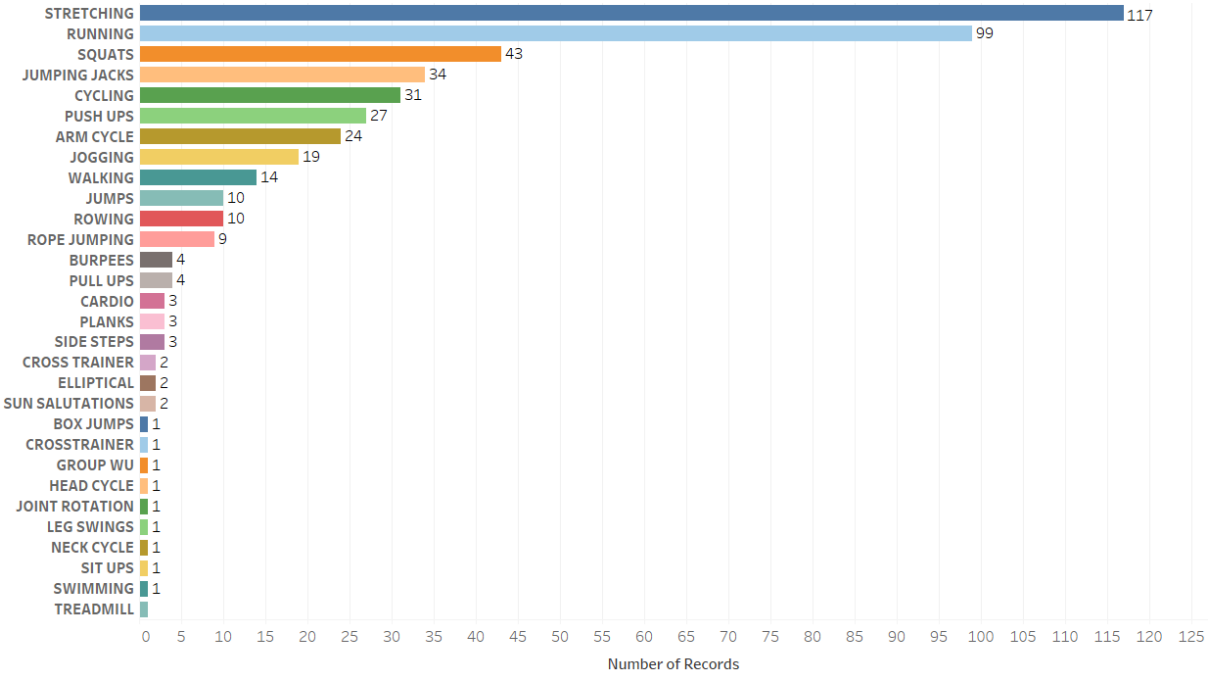

FIGURE 5.12: Summary of most common warm up exercises performed by the respondents

According to [22], "*stretching neither prevented nor induced injury when compared with not stretching before running*" . In some cases it can even inhibit performance [96]. The authors in [96] point out that static muscle stretches which are longer than 60 seconds are more likely to lead to a slight to moderate reduction in performance. Hence, we believe that, by using our gamified solution, not only that athletes can prepare themselves for the subsequent physical exercises but also be more informed about the most efficient and practical movements that presumably reduce the likelihood for injuries and increase body performance for the subsequent physical activity. The second most common exercise was running (indoor and outdoor). The respondents usually start their warm up with a few minutes run after which they perform a full body stretching exercises. Apart from that, exercises like squats, jumping jacks, push-ups, arm cycles, and cycling were also common exercises among the respondents. Some respondents, on the other hand, use treadmill, cross trainer, rowing and elliptical exercise machine for warming up. From the answers, we can conclude that respondents mostly focus on warming up their lower body parts in their warm up routines and in general finish the warm up routine with whole body stretching exercises. We also notice that most of the respondents do not follow any specific warm up routines and use general exercises before sports activities with strong focus on whole body stretching. Certain number of respondents, on the other hand, did not only list but described an exemplary warm up routine.

Some of them are:

- "*Warm up depends on exercise: e.g. warming up for heavy squats includes hip-opening exercises, core static exercises, mobility exercises for hip rotation/extension, low-weight squats.*"
- "*For climbing: running on the spot, arm cycles, ankle rotations, active and passive stretches of leg, arm and back muscles. For running: running on the spot, ankle rotations, active and passive stretches of leg muscles.*"
- "*I start with an activity to raise my heart rate and body temperature. Once that's accomplished, I work through stretching the major muscle groups first, then typically sit down to stretch out smaller/more specific muscle groups.*"

Based on these answers we introduce new movements for avoiding obstacles and collecting points in our second release of the warm up game. As for the respondents, our main focus are lower body parts. Even though it is expected by the respondents, stretching exercises will not be incorporated. However, we inform the athletes after the game ends about the most preferred stretching duration they can perform in order to maximize the subsequent performance and, possibly, avoid injuries. Since we are using only one Kinect device for gesture tracking, we avoid complicated movements that require prior exercise knowledge or experience and increased focus. Moreover, taking into account our hardware constraint, we choose movements that are easily detectable with only one Kinect sensor.

5.3.4 Reasons for Not Warming Up

Respondents who reported not warming up regularly have been inquired about the reasons for not doing it. Out of n = 195 respondents who reported not warming up regularly before sports activities, total of n = 321 responses have been collected, since some of the respondents gave multiple answers to this question. The most common reasons reported by the respondents were time constraint which was reported by n = 84 respondents and the monotonous and tiresome nature of the warm up procedure, reported by n = 81 respondents. Furthermore, n = 41 respondents pointed out that the reason for not warming up was because they do not know how to properly carry out the warm up procedure, while for n = 37 respondents stated that the warm up procedure represents an insignificant and negligible activity. Figure 5.13 shows the respondents' answers regarding reasons for skipping warm up exercises before physically more demanding exercises.

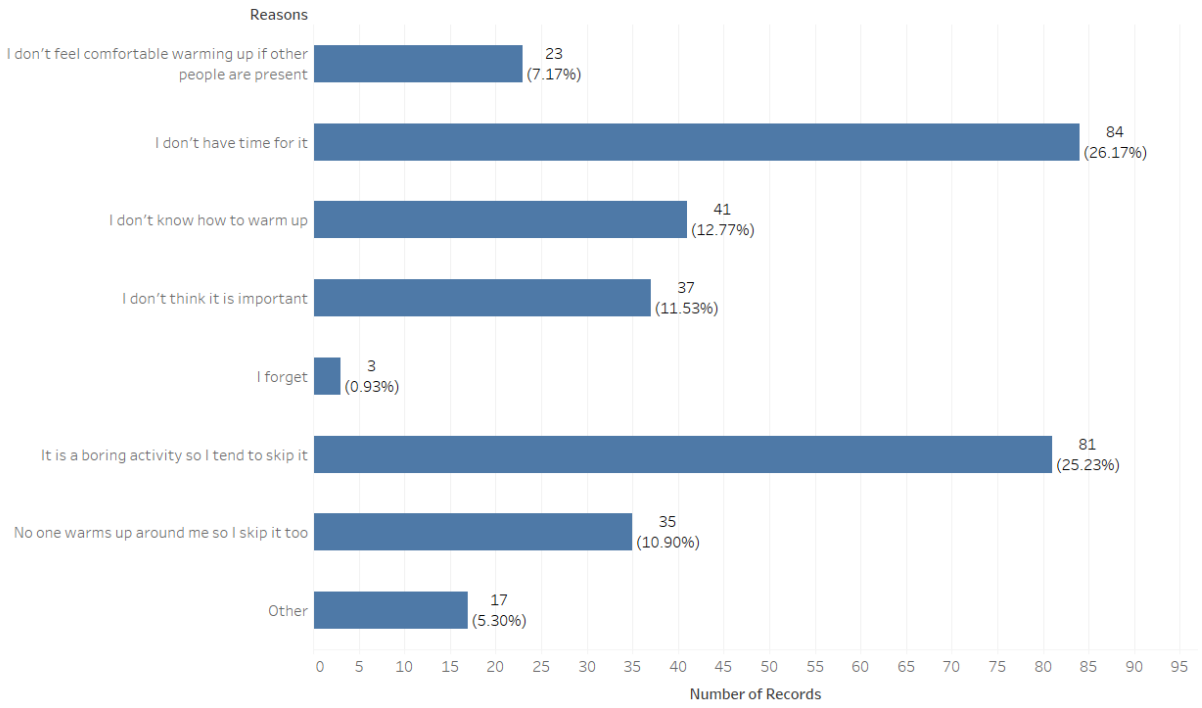

FIGURE 5.13: Sum of Number of Records for respondents' reason for not warming up.

Since this was an open ended question, a number of respondents left a comment regarding reasons for not warming up. We group all these answers in the Other category. Some of the other reasons for avoiding warming up pointed out by n = 17 respondents were:

- "*I train climbing, so sometimes I can't wait to start climbing and skip the warm up.*"
- "*When I bike (for commuting) or do yoga, I don't warm up before, as I don't find it necessary.*"
- "*I do a lot of endurance sports like running or biking. Warming up is kind of built in. If I do intervals, I do warm up.*"
- "*It depends on the type of exercises - if I'm going for a bicycle ride I will skip warm up.*"
- "*I feel it is better for me to warm up by playing the game.*"
- "*It is part of the exercise. I dance, so the warm up is a dance routine.*"

We conclude that the reasons for not warming up are mostly tied to the specifics of the sports, as well as the respondents' beliefs that it is not of a crucial importance for the sports they engage in. That is, the respondents are under the impression that warm up for sports like biking, climbing or dancing are part of the exercise and they do not find it necessary to spend time for additional exercises that can prepare them for physically more demanding ones.

In Figure 5.14 we present the respondents' answers regarding reasons for skipping warm up session before physically more demanding exercises broken down by their gender.

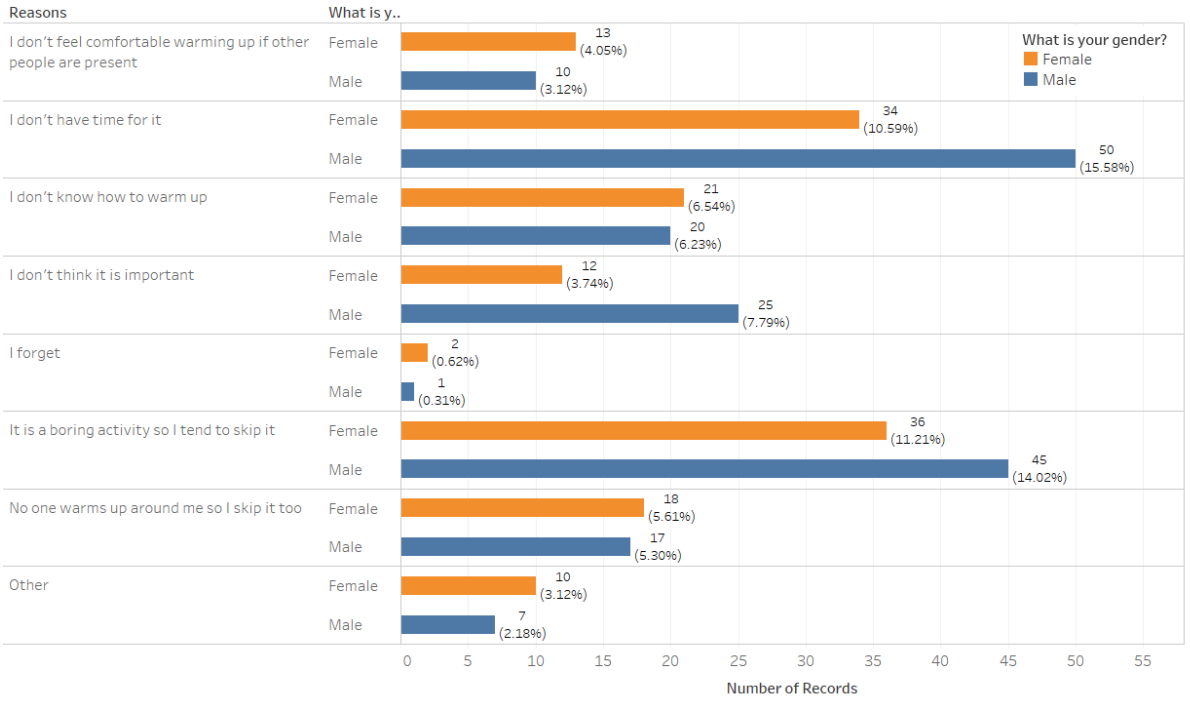

FIGURE 5.14: Sum of Number of Records for respondents' reasons for not warming up sliced by respondents' gender.

From the responses depicted in Figure 5.14, we observe that there were more male respondents that reported time constraints, dullness, and meaningless of the warming up procedure as main reasons for not warming up before sports activities. On the other hand, more female respondents reported not feeling comfortable warming up when other people are present, not knowing how to perform the warm up procedure and avoiding warm up exercises because no one is doing it as main reasons for not warming up before sports activities.

In Figure 5.15 we present the respondents' answers regarding reasons for skipping warm up routine separated by their preferences toward warming up alone, with a friend or in a group. We notice that the most number of respondents who reported not warming up due to time constraints (n= 51), monotonous (n = 47) and, for them, meaningless nature (n = 25) of the warm up procedure usually engage in sports activities alone. Moreover, we observe that individuals tend to skip warm up more in cases when no one warms up in the group they are part of. That is, respondents who reported preferring sports activities which are carried out in a group or with a friend are likely to skip the warm up procedure if no one in the group engages in the warm up routine. In addition, this was the only case where a reason for not engaging in warm up had more responses in a category of respondents that usually work out with a friend or in a group. For all other reasons, most of the respondents belong to a category in which individuals reported engaging in sports activity usually alone.

Hence, we conclude that individuals who carry out a sport activity alone, are more likely to skip the warm up routine than the ones doing it with a friend or in a group.

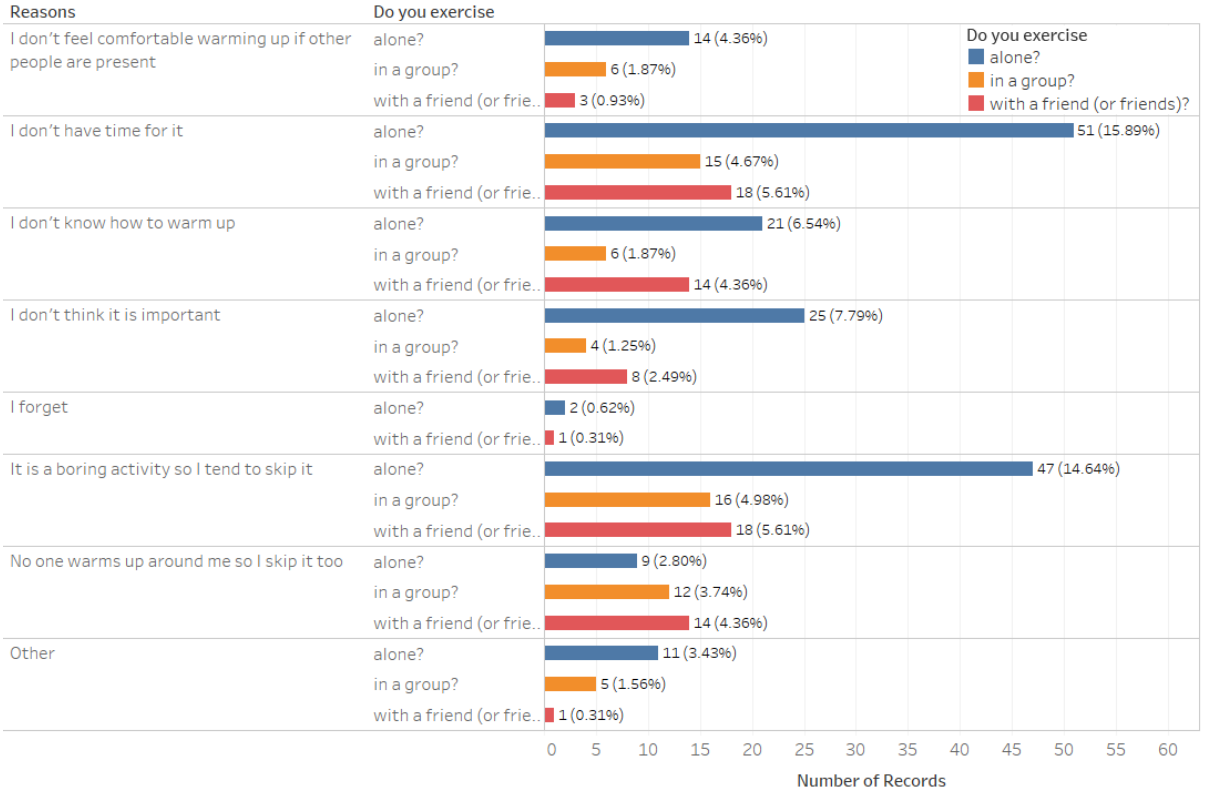

FIGURE 5.15: Sum of Number of Records for respondents' reasons for not warming up sliced by respondents' work out preferences.

Overall, the results obtained in this question align with the ones acquired by researchers in [25] for their survey on golfers and their warm up habits This further confirms the assumption addressed in this thesis and justifies the need for a solution that will motivate athletes to warm up more regularly before sports activities.

Considering all the physiological and psychological benefits of a proper warm up routine and its suggested role in injury prevention covered in Chapter 2, it is still perceived as a tiresome and meaningless activity and hence avoided by many amateur and professional athletes. Thus, educational and motivational solutions, that are enjoyable and easy to carry out, with primary focus on the major muscle groups and benefits of warm up need to be developed and implemented in order to increase the proportion of athletes who engage in warm up routines before every strenuous exercise. With the Immotion warm up game, we tackle these issues brought up by the respondents. Making the game interactive and appealing, with intervals that last as long as the player chooses to, the warming up procedure undergoes a shift from a repetitive and tiresome activity to an entertaining and challenging necessity. Time constraints, mentioned by n = 34 female and n = 50 male respondents, will not be prevalent, since the player can choose the duration of the warm up session and by doing so plan ahead the work out session.

These values are derived from the most common warm up duration reported by the respondents in Figure 5.7. Furthermore, athletes who do not know how to warm up and which movements to perform (mentioned by n = 21 female and n = 20 male respondents) in order to prepare their body for the subsequent sports activity, will be instructed through the game to perform a set a general movements. We believe that the guidance offered in our exergame could make the warm up routine more inviting for athletes who most often avoid or do not know how to perform the warm up routine properly. Moreover, we hypothesize that, if the athletes are provided with the opportunity to warm up using our gamified solution, which is tailored for a general warm up routine, will warm up more regularly. In addition, our solution could hypothetically leverage the duration of a warm up routine. To test these hypothesises, in this survey we assessed and analysed the general acceptance of our prototype version of the gamified solution for warm up. The results obtained are discussed in detail in the next section.

5.3.5 Questions Related to the Immotion Exergame

In the last part of the survey, the respondents were shown a short video with the prototype of the Immotion exergame. The video presented a warm up session performed using our prototype exergame. The prototype consisted of 7 different segments. In each segment a specific movement needed to be executed. The video lasted for 2 minutes and the required movements included:

- jump right,
- jump left,
- jump up, and
- squat.

After the video, the respondents were asked a set questions related to the exergame and warm up session executed in order to evaluate the general acceptance of the presented gamified solution for warm up.
Firstly, the respondents were asked if they would use the game for warming up before physically more demanding exercise. The pie chart in Figure 5.16 shows the number and percentage of respondents that would use the prototype game for warming up, and the number and percentage of the respondents who would not use the prototype game for warming up. From the information shown in this pie chart the green area resembles those who would use the Immotion game for warming up n = 269 (60.31%) while the red resembles those who would not use it n = 177 (39.69%). This question was asked from all the respondents (n = 446) regardless of their warm up preferences. From Figure 5.16 we conclude that the general acceptance of our gamified system is positive.

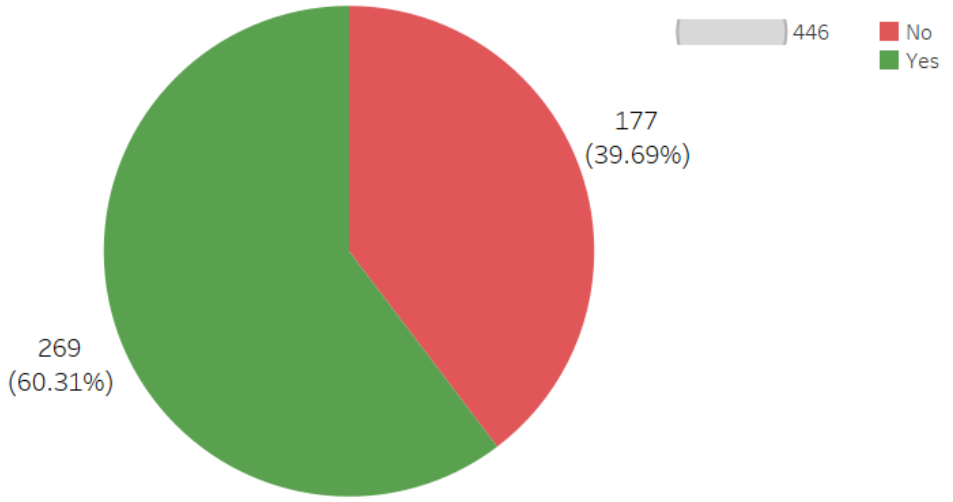

FIGURE 5.16: The Sum of Number of Records and Percentage of Total Number of Records for question "*Would you use the Immotion game for warm up?*"

If we assess the respondents age compared to the Immotion game usage, we observe that the game is generally accepted by the respondents between age 22 and 37 years old. Negative responses concerning the warm up game usage are received from the respondents who were older than 38 years. The age and exergame acceptance trend is shown in Figure 5.17.

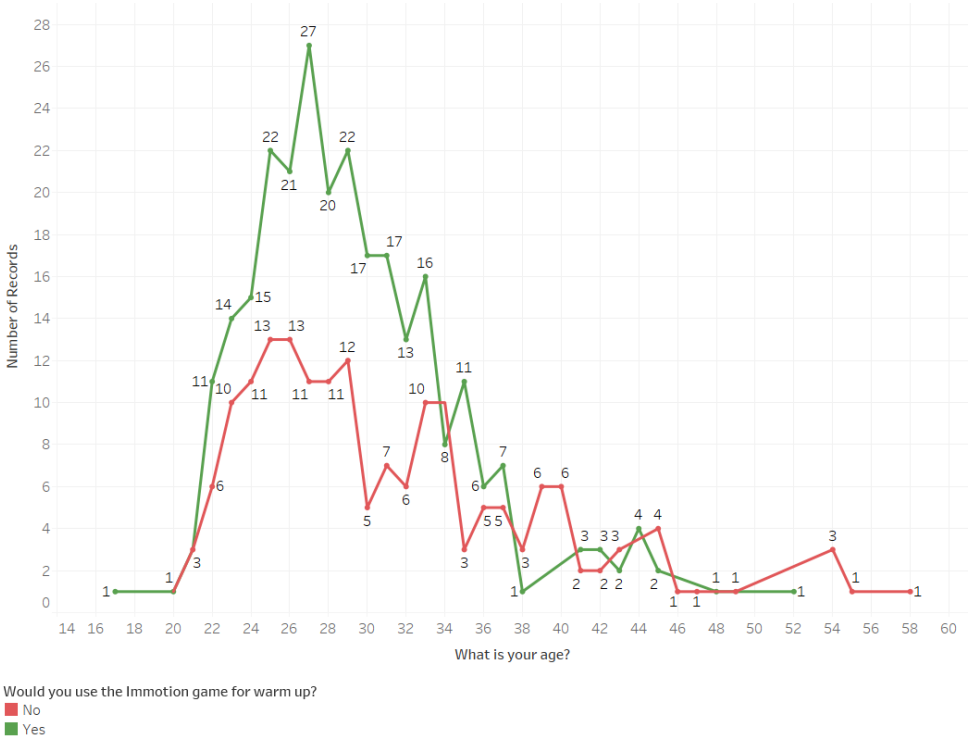

FIGURE 5.17: The trend of sum of Number of Records for question "*What is your age?*". Color shows details about responses to the question "*Would you use the Immotion game for warm up?*"

Next, the acceptance of the Immotion warm up game regarding respondents' preferences towards warming up before a physical activity is depicted in Figure 5.19. Out of n = 195 respondents who reported not warming up before sports activities n = 124 (63.58%) would use the Immotion game for warming up. On the other hand, out of n = 251 respondents who reported always warming up before sports activities, n = 145 (57.76%) would use the Immotion game for warming up. We observe that the general acceptance of the game is relatively high in both categories of respondents. However, respondents falling into category of athletes who do not warm up regularly gave more positive answers compared to the athletes who warm up regularly.

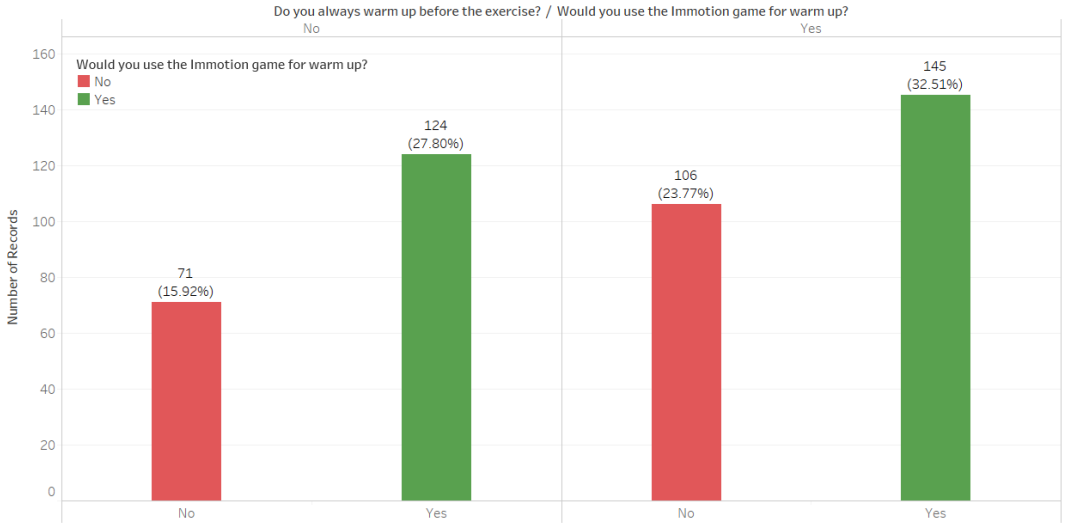

FIGURE 5.18: Sum of Number of Records for the question "*Would you use the Immotion game for warm up?*" broken down by responses for question "*Do you always warm up before the exercise?*". Colour shows details about question "*Would you use the Immotion game for warm up?*"

This might imply that our gamified system is more appealing to respondents who do not engage in warm up routines often, and hence, could motivate them to warm up more regularly, or at least, more than they do currently. Also, high acceptance of the warm up game in the category of athletes who warm up regularly also tells us that those athletes, even though reported having well established warm up routines, would possibly switch to our solution if they are presented with the option to do so.

Since the player of the Immotion game is instructed when and what sort of movements to preform, we were interested in acceptance of the exergame among those respondents who prefer warming up when given instructions. Out of n = 251 respondents who reported warming up regularly before sports activity, n = 97 stated not preferring having given instruction during the warm up exercises and n = 144 respondents stated that they prefer warming up when given instruction. From Figure 5.18, we observe that out of all the respondents who do not like warming up when given instructions, n = 50 respondents stated that they would not use the Immotion warm up game, while n = 47 respondents stated that they would use it.

Contrarily, among respondents who prefer having instructions during warm up exercises, n = 56 stated that they would not use the warm up game, while n = 98 respondents reported that they would use it.

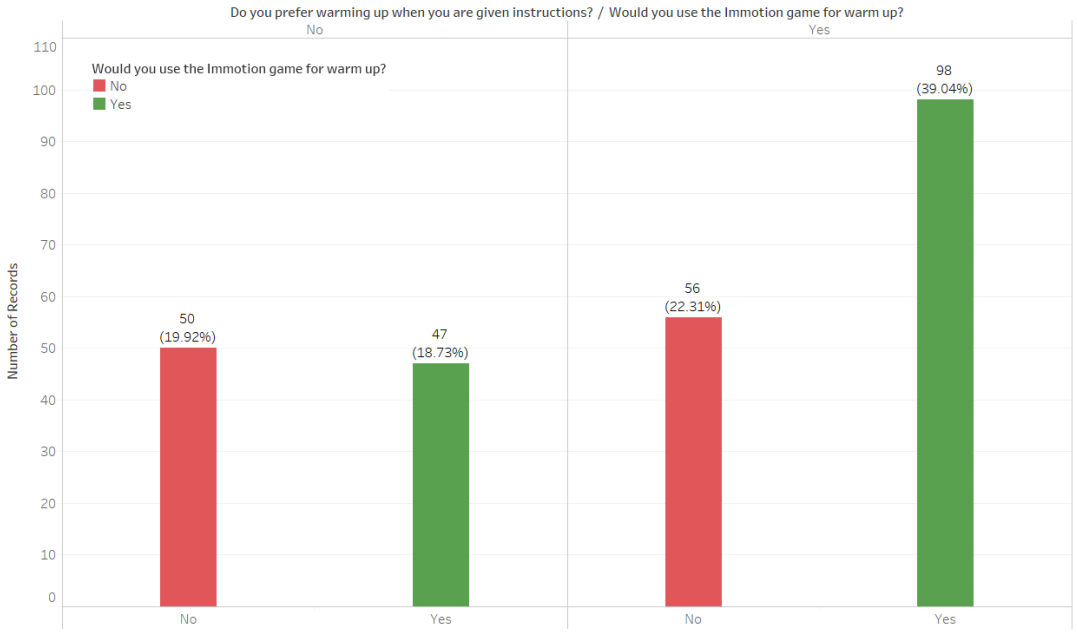

FIGURE 5.19: Sum of Number of Records for the question "*Would you use the Immotion game for warm up?*" broken down by responses for the question "*Do you prefer warming up when you are given instructions?*". Color shows details about the question "*Would you use the Immotion game for warm up?.* "

We observe that the acceptance of the warm up game is much higher among those respondents who prefer warming up when given instruction and conclude that our gamified solution is more appealing for individuals who prefer warming up when given instructions. This also suggests that the warm up guidance and instructions that are provided by our solution, could hypothetically influence individuals to engage in warm up routines more regularly. Lastly, we analysed the warm up game acceptance broken down by respondents' preferences toward warming up alone, with a friend or in a group. In Figure 5.20, the respondents' answers are first sliced into categories based on the fact that they do or do not warm up before sports activities, and then broken down into subcategories based on their preferences toward warming up alone, with a friend or in a group. We observe that the general acceptance of the warm up game is high in each subcategory (alone, with a friend, in a group) of respondents. The highest acceptance is among those athletes who prefer exercising alone (regardless of they warm up or not). The only subcategory where the disapproval of the gamified approach was higher than its acceptance, was among those respondents who warm up regularly and prefer exercises that are carried out in a group. We believe that the reason for this is the fact that the Immotion game, as shown in the video to the respondents, is a single player game which instructs the player to perform a set of general warm up movements and not a multiplayer game that is built for group exercise sessions.

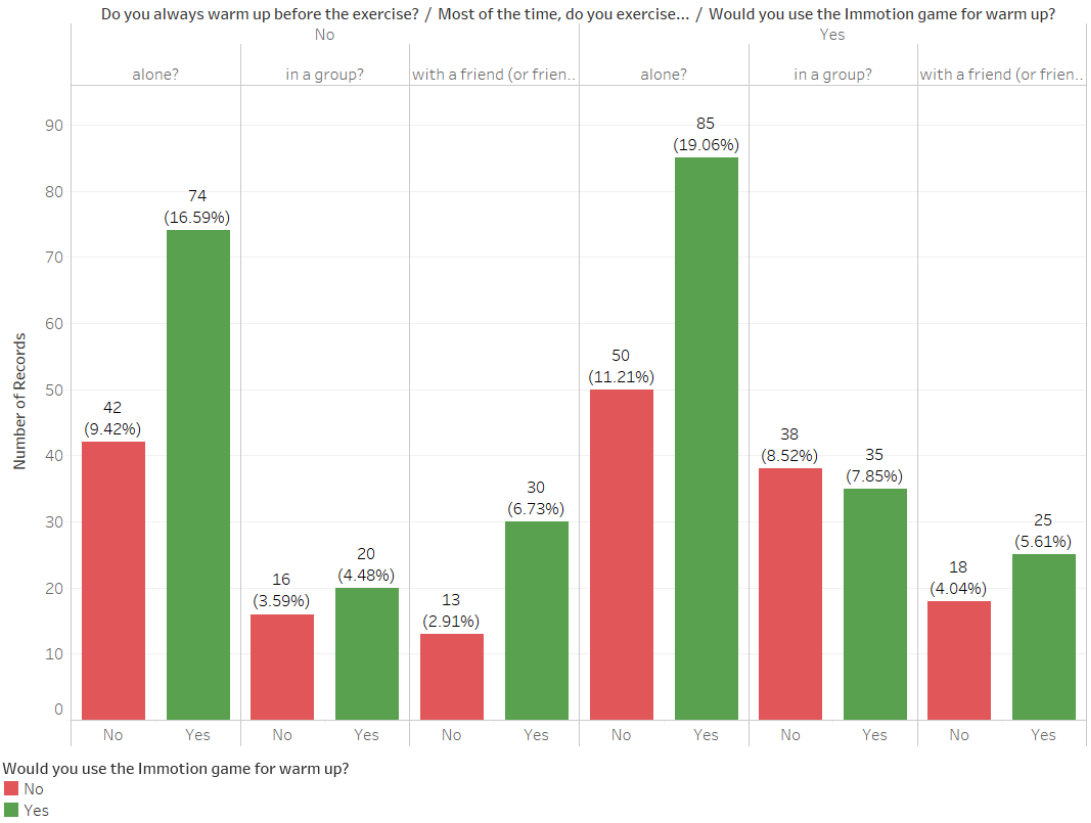

FIGURE 5.20: Sum of Number of Records for respondents' answers to "*Would you use the Immotion game for warm up?*" broken down answers to "*Do you always warm up before the exercise?*" and "*Most of the time, do you exercise alone, in a group or with a friend*". Color shows details about answers to "*Would you use the Immotion game for warm up?*"

Respondents who engage in group (team) sports might not feel it useful to spend time on general warm up exercises if the sport they engage in require specific movements. Furthermore, in exercises that are carried out in a group, it might not be time efficient to wait for every team member to complete the warm up routine using the proposed warm up game. That is, our proposed solution is not practical for the use case where athletes engage in group sports or exercises. This information, nevertheless, suggests that the target group for the Immotion warm up game should be individuals who prefer exercising alone or with a friend regardless if they warm up before sports activities or not.

To assess respondents' attitude towards the Immotion warm up game showed in the video, the respondents (n = 446) were asked to give their preferences regarding the following statements:

- "*I would rather use standard warm up routines instead of gamified warm up.*"
- "*This approach (showed in the video) can increase the duration of my warm ups.*"
- "*This approach (showed in the video) can increase the quality of my warm ups.*"
- "*This approach (showed in the video) can make warm up more enjoyable for me.*"

- "*This approach (showed in the video) can never work in practice for me.*"
- "*This approach (showed in the video) could motivate me to warm up more regularly.*"

For each question, respondents could choose among five categories: Strongly Disagree, Disagree, Neutral, Agree, and Strongly agree. Each category is assigned a score from 1 (Strongly Disagree) to 5 (Strongly Agree). Figure 5.21 shows the Likert scale score for the previous statements sliced by respondents' preferences towards warming up before sports activities.

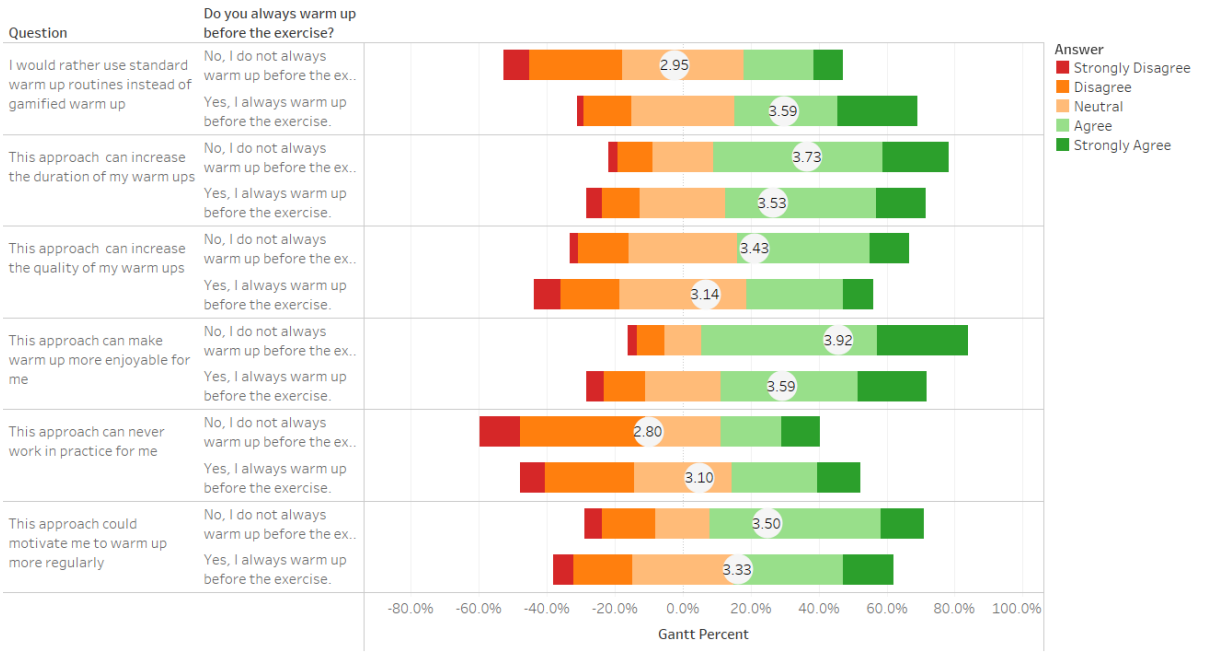

FIGURE 5.21: Gantt Percentage and the average score for question "*Do you always warm up before the exercise?*" broken down by statements regarding the Immotion warm up game.

As in Likert scale presented in Figure 5.11, for each question we assigned a range of values that show how the survey responses are spread by available categories and a general feeling whether they are positive or negative. Based on the available categories and their total scores, we specified the dividing line and checked how many responses are below and above it. Each individual line shows a different starting point for each answer. The overall score (or the number of responses) for all the question is the same, since these questions were mandatory and all respondents answered it (n = 446). The width of each individual category depends on the number of records that are in that category over the total number of responses for the entire bar (that particular question). Lastly, we added the overall Likert scale score (LSS) depicted as a white circle in each bar which shows the summary for each individual question. From Figure 5.21, we observe that respondents who reported warming up regularly would rather use standard warm up routines instead gamified warm up solutions, like the presented Immotion warm up game (LSS = 3.59).

On the other hand, respondents who do not warm up regularly mostly disagreed with the statements ("*I would rather use standard warm up routines instead of gamified warm up.*") or gave a neutral answer (LSS = 2.95). To be precise, n = 15 respondents strongly disagreed, n = 53 disagreed and n = 70 gave neutral answer out of n = 195 who reported not warming up before sports activity. This suggests that most respondents falling into this category would likely use our gamified solutions as part of their work out (sports) routines. Regarding the second ("*This approach (showed in the video) can increase the duration of my warm ups.*"), third ("*This approach (showed in the video) can increase the quality of my warm ups.*") and sixth ("*This approach (showed in the video) could motivate me to warm up more regularly*") statement, both categories of respondents gave generally positive answers. However, respondents who warm up regularly gave more neutral answers (n = 63, n = 94, and n = 75 out of n = 251) which indicates their uncertainty about the possible positive effects this gamified solutions can have on the duration and the quality of the warm up procedure. Similarly, in the fourth statement ("*This approach (showed in the video) can make warm up more enjoyable for me.*"), responses given by both category of respondents were generally positive (LSS = 3.92, LSS = 3.59). This was, also, the statement that had the highest acceptance among respondents who do not warm up regularly. Overall, the results suggest that both categories see the gamified approach as a way of making the warm up routine more enjoyable and satisfying. The fifth statement ("*This approach (showed in the video) can never work in practice for me.*") received lover score (i.e. negative answers) from all the respondents. This corresponds to the previous results and suggests that respondents would presumably include this approach in their exercise routine if presented with the option. Lastly, all respondents were asked to leave their comments regarding the features they liked or disliked about the presented prototype. For all answered questions, we grouped the answers based on textual occurrences of specific keywords and on textual occurrences of keywords with the same semantic meaning. In Figure 5.22 we present the summary of responses regarding question "*What do you think are the most important features of this warm up game that would make you use it?*". From Figure 5.22 we observe that most of the respondents see the game as a fun, entertaining and enjoyable way for engaging in the warm up routine; a "*very new and creative idea to warm up*". According to the respondents, this warm up game would be the most useful "*for people that do not warm up or do not know how to warm up*". This statement aligns with our assumption also. We believe that athletes who rarely or never warm up, as well as athletes who do not know how to perform a warm up routine would benefit from the presented gamified solution for warm up the most. Next, the respondents appreciated the guidance in the game, in a sense that they are instructed to which movements to perform through avoiding obstacles and collecting coins:

- "*Very simple direction on what to do, once you get the mechanic of what the game is trying to get you to do you don't really have to think much about the varying motions asked of you, you're just trying to hit the orbs by moving your body as necessary.*"

Moreover, they enjoyed the interactive element the game provides through the Kinect sensor, the gamification elements (coins) placed in game scenes, and that it is made easy to follow.

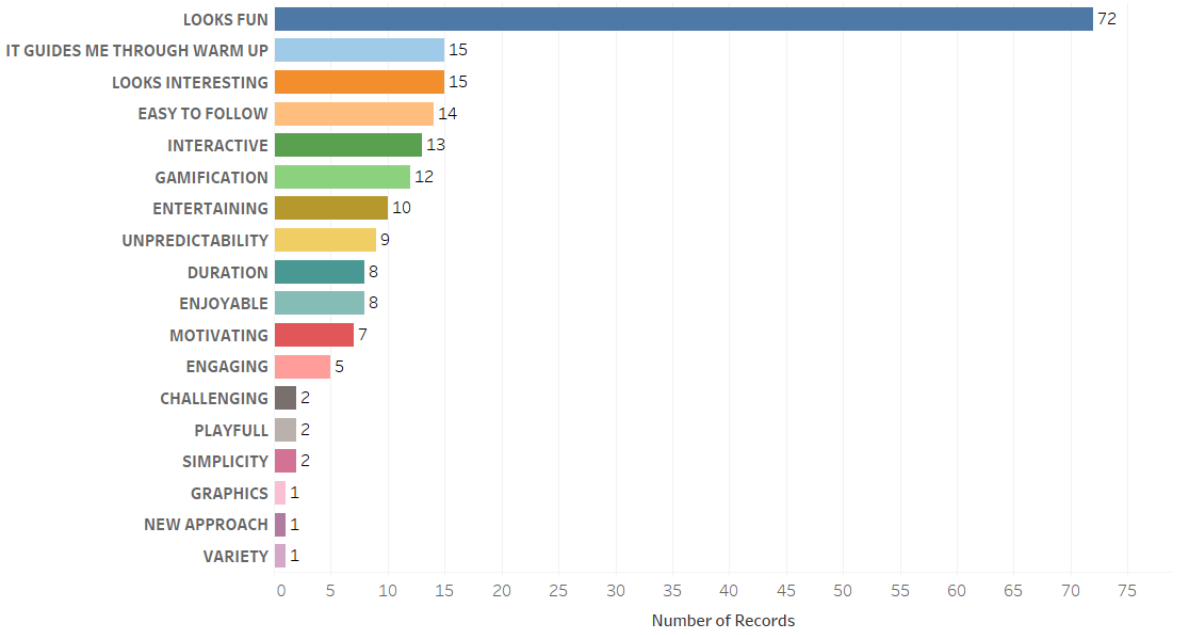

FIGURE 5.22: Aggregated answers for question: "*What do you think are the most important features of this warm up game that would make you use it?*"

The obstacles and coins are situated in a way that is easy to understand which movement is required to perform in order to avoid the obstacle or collect more points and, thus, finish the game successfully:

- "*The game makes me unconsciously do a proper warm up without me thinking about the procedure and the exercises a lot.*"
- "*Performed motions are changing often, definitely more interesting than 30 jumping jacks.*"

Also, some of the respondents appreciate the short duration of the game because it can easily fit in their work out routine. In addition, they point out how this approach could motivate them to start their work out session with warm up and potentially influence the duration of the warm up exercise too. They attribute this to the gamification of the warm up routine and the immersive nature of the game that acts as a distraction, in a sense that, it engages the user and shifts users' focus from a tiresome warm up activity:

- "*It's immersive - it would feel like a game and not a boring warm up routine.*"
- "*Engaged without realizing.*"

- "*It would increase the duration of my warm up - time passes faster when you are distracted by a video.*"

Furthermore, the short and fixed duration of the game seems to be appealing to the respondents as well. By knowing exactly how long the warm up session will last, they believe that their work our session could be planned better.
In order to gain insight into elements of the game the respondents dislike the most, we asked them to point out the features, elements and main aspects of the game they would change or remove completely. These answers gave us more information about respondents' attitudes towards the presented warm up game and their stand about gamified solutions of exercises in general. Based on these answers and suggestions, we added new features and modified exiting ones, in order to have a gamified solution for warm up that fits respondents', and presumably future users', needs the most. Our goal is to offers a solution that can be used before every exercise and sports activity, and having elements and features users expect and desire the most, will make the game more appealing and, thus, more regularly used. Figure 5.23 shows the summary of responses regarding question "*What do you dislike about this warm up game with regard to the general idea (using game to motivate users to warm up more regularly)?*" One of the interesting aspects that was captured during this survey is the main reason why respondents would not use the game. From the results presented in Figure 5.23 we notice that most of the respondents pointed out the hardware (i.e. Kinect sensor, projector and large screens) and its price as the primary argument for not using the game. Surprisingly, from the video that was shown, the respondents assumed that in order to use the game, one must acquire all the necessary hardware and use the game at home before the sports activity:

- "*It's too impractical. I can't find a dark room with a projector before I play football or cricket.*"
- "*No way would I warm up in one location (living room) before going to exercise.*"
- "*Jumping disturbs the neighbors (next door and downstairs) when living in an apartment; prefer warm up outside*"

Taking this into account, the negative bias is acceptable. However, as mentioned before, the game is intended to be used in gyms, fitness and sports centers, and it is not designed to be a solution for home work outs and exercises. Since exergame solutions that are intended to be used at home already exist on the market, our goal is to completely focus on the warm up gamified solution as a preparatory activity before sports sessions and to make it available and usable in places where individuals come to engage in some sort of sports activity. That way, we hypothesize, our approach will be more likely utilized, compared to home work out solutions.

In addition to this, respondents who prefer sports and work out exercises outdoor, mostly disliked the fact that the game is intended to be used indoors without any option to be installed and used in open space. This was the second most argued reason for not using the presented game:

- "*The issue is that the game has to be setup where I do my sport, which is probably not going to happen (forest)*"
- "*You need to do it in a room with a screen and a device, this is a strong constraint if you want to practice sport outdoors*"
- "*Most of my warm ups take place outside, and so it may not work outdoors very easily*"

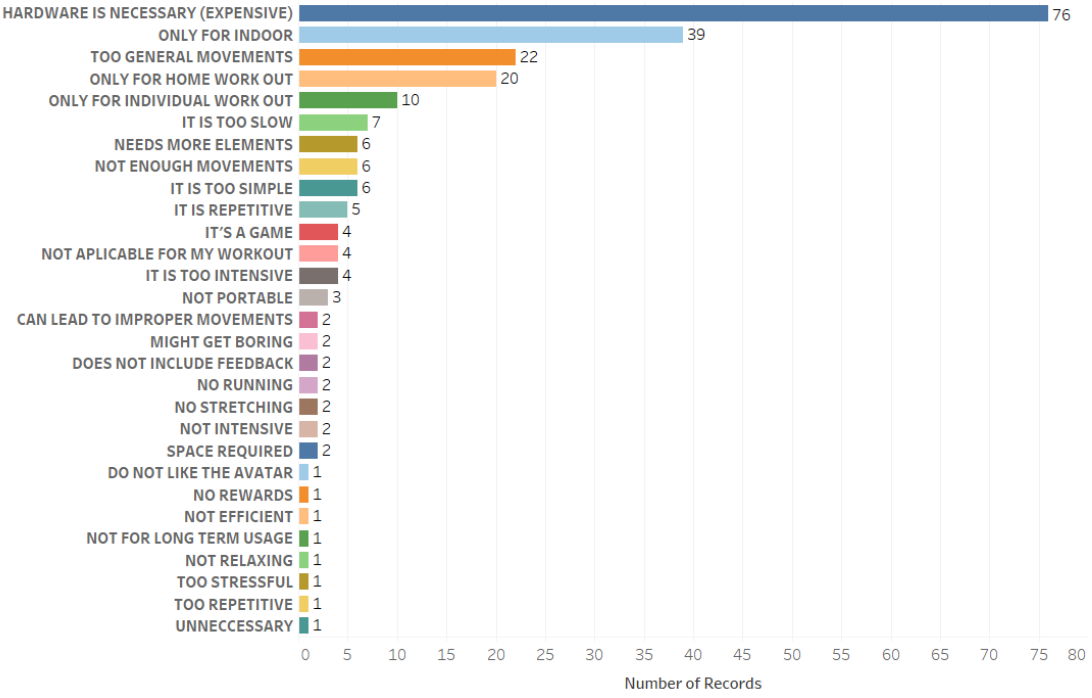

FIGURE 5.23: Aggregated answers for question: "*What do you dislike about this warm up game with regard to the general idea (using game to motivate users to warm up more regularly)?*"

They propose having a portable version (mobile application) of the game that can be used without any space or hardware constraints..These recommendation will be further assessed later in this chapter.
Furthermore, the respondents pointed out that only few movements (exercises) are required in the game which makes it one-dimensional, neglecting the warm up for arms and upper body:

- "*Very limited range of motion, hard to imagine it would capture all required muscle groups one should normally warm up.*"

We assume that the reason they found the movements too general and repetitive is because only few exercises and movements were included in the prototype that was presented to them. The prototype had 7 segments and only 4 segments contained obstacles with coins. In the prototype game, the obstacles were avoided and the coins collected using jumps and right and left movements, depending on the position of the game elements. Introducing only limited number of segments and requiring only few movements were determined to be sufficient to present our idea of gamified warm up and assess its general acceptance. For the second release of the warm up game, based on the respondent' answers regarding most common movements and exercises they reported performing during warming up (Figure 5.12), we extended the number of movements required to carry out in order to successfully finish the game. We believe that we captured and implemented the most common exercises and movements reported by the respondents that are, first, detectable with high accuracy using only one Kinect device and, second, accomplished easily without no prior exercise knowledge or experience. Moreover, we decided to discard and not implement movements that are reported by most of the respondents but require additional equipment in order to be performed, like pull-ups, rowing and rope jumping. Next, the respondents mentioned the lack of group (or multiplayer) exercises using the game. Since some of the respondents often engage in group sports, they would expect that the game also includes a version where they can compete with someone while warming up, or just warm up using the game together with the group they exercise with:

- "*You could design the game so that it is competitive. You could compete with other players for a high score, and this could become a group activity and become a part of exercise routines. This way, it would also become easier for you to drag someone who doesn't exercise regularly to start doing so.*"

This requirement was brought up by many respondents. According to the them, this feature is necessary for group sports sessions. Introducing this feature could make the game more enjoyable and boost the competitive aspect of the game:

- "*It's not practical if you exercise in groups. In this case everyone would need their own screen, which seems like too much of a hassle just to warm up.*"

The simplicity of the scenery, used avatar and lack of diversified game elements was also addressed. According to the respondents, the absence of these elements can potentially make the game monotonous and uninteresting after a while. If the game is lacking captivating visuals and scenery, compelling challenges and intriguing story line, users will stop using it after the initial incitement for the game ceases. Taking this into account, we introduced new segments with elements that make the game more appealing and the challenges more attractive in the final exergame.

We increased the number of segments from 7 to 20 and completely changed the scenery previously presented in the prototype game. Regarding types of exercises performed in the game, many respondents expressed their concerns that stretching exercises are not included in the required movements:

- "*Depending on the efficacy, I would want to incorporate stretching as part of the routine. Even if it was doing some motion detection for active stretching in a direction to pop balloons or something.*"
- "*... does not stretch ligaments for my sports (body building)*"

Since stretching is part of most respondents' warm up routine, they expect that the game also contains movements and exercises of this type. They proposed having movements that focus on whole body stretching, stating it helps them to prepare more for the subsequent physical activity. This statement is surprising since research, as previously discussed, has never found stretching warm ups to have any benefits in preparing our body for strenuous activity or injury prevention [22]. Thus, we chose not to incorporate stretching exercises as required movements in the final release of the game. However, at the end of the game, athletes will be informed about the duration of stretching exercises assumed to be the most beneficial for the subsequent activity. Lastly, the respondents pointed out that the intense focus on the screen could potentially lead to improper execution of the body movement and thus, lead to injuries:

- "*When you're not focusing on your movements, you are at a higher risk for injury. Additionally, muscles are more responsive when you're consciously engaging them.*"
- "*I worry that I would not use proper technique when playing the game and therefore not successfully warming up.*"

The respondents suggested implementing a solution that monitors the correctness of the movements performed and, in case of incorrect ones, informs the players in a way it does not affects their performance in the game as a form of a feedback:

- "*I think having an interactive screen that takes you through a proper warm up and can educate you on how to properly warm up each muscle and what each movement is warming up would be a great idea.*"

The respondents also argued that the game requires movements that are too generic and not applicable for the sports they engage in. These athletes perform specific warm up exercises that are either too complex to be captured with high precision by the Kinect sensor, or are executed in environment not suited and intended for our gamified solution (e.g. swimming).

In summary, we focused on more general exercises that are simplistic, presumably known by the athletes, and can be captured with high accuracy using one Kinect sensor. Moreover, in our solution we wanted to avoid stretching exercises because they do not provide protection from muscle soreness, they do not seem to contribute to the reduction in the risk of injury and, lastly, there exists insufficient research to support its effectiveness on sporting performance. Figure 5.24 shows the summary of responses regarding question "*In your opinion, what features does this game have to possess in order to be used on a regular basis?*".

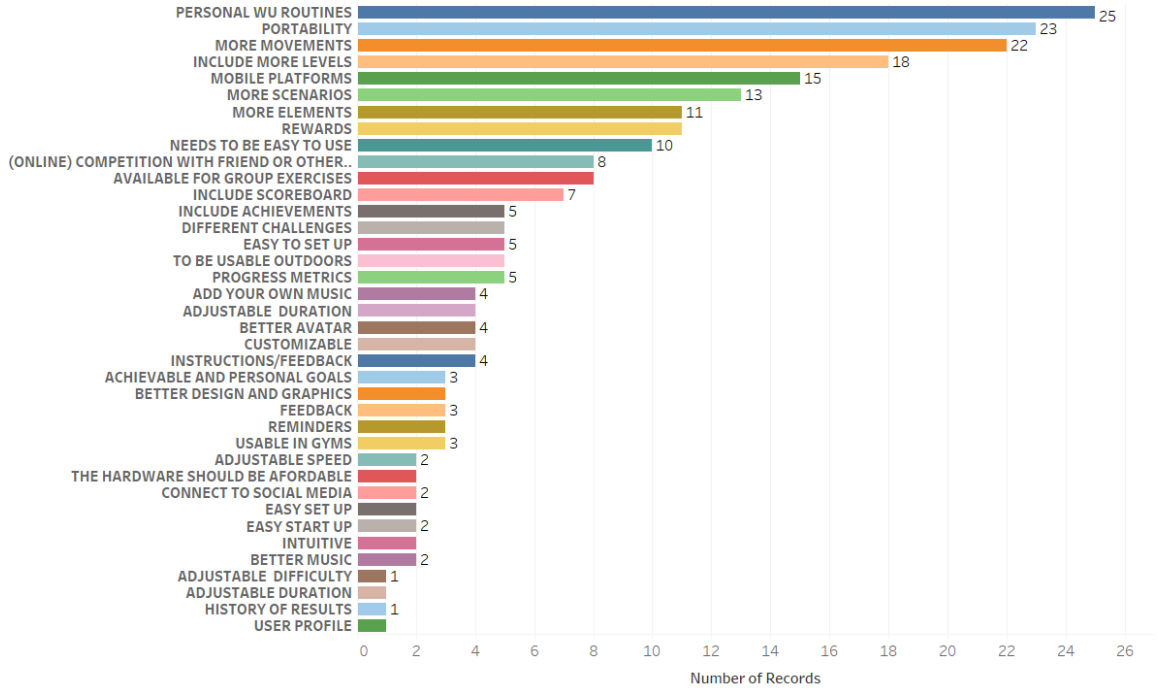

FIGURE 5.24: Aggregated answers for question: "*In your opinion, what features does this game have to possess in order to be used on a regular basis?*"

With this question, our goal was to gain insight into possible features the respondents would look forward to and benefit the most from, in a gamified solution like the presented prototype. Based on these answers, ideas, and recommendations we modified our exergame in order to be more appealing to the future users. From 5.24 we observed that the most of the respondents would enjoy having a gamified solution that is tailored specifically to their needs. That is, the respondents would like to have the option to customize the warm up routines in the gamified system. According to the respondents, the warm up movements should be adapted to the sport of choice and should also change overtime to avoid the routine being too repetitive. Namely, the warm up routines should be sports specific, and not general as in the presented video:

- "*It would be great if the game had different types of warm ups based on two things: type of sport activities, which I am about to start (e.g. running, cycling, etc.) and if I have some specific preconditions, like back pain.*"

- "*... different levels (for amateurs and for more professionals), different warm ups for different sport activities (e.g. warm up for a run or warm up for a HIIT session)*"

Moreover, the game should also take into account any physical injury users have. That is, individuals should be in position to discard some of the movements in case they are not able to perform them. In addition, adjustable game setting were also addressed. The respondents would rather enjoy having a game with adjustable game elements (segments and avatar), speed, duration, and number and types of obstacles. That way, they would be in control of the movements that are needed to be performed, as well as, their intensity and speed. This requirement is actually tightly connected to the one previously mentioned. The respondents would prefer the most to be able to manage and manipulate all the game's features conforming them, by doing so, to their work out preferences. Portable (and mobile phone) version of the game, as in the previous question, was also pointed out by the respondents:

- "*As with team sports, location changes weekly so if this game was able to be moved with the team then this would help.*"

Users who engage in sports outdoors or whose work out location changes often, would prefer having a mobile application that helps them warming up. Moreover, the respondents would rather enjoy a game that has more levels with different sceneries and difficulties. Each level, according to respondents, could be at different difficulty level, including new obstacles and, hence, require new movements in order to avoid those obstacles. This way, they believe, the game would stay enjoyable and captivating for a longer period of time:

- "*Interesting and achievable goals, something new all the time, new routes, obstacles, etc.*"
- "*More movements and as time goes by, the speed of the obstacles you approach should be faster, different and finally a short cool down at the end like just walking for a minute.*"

We believe that introducing multiple levels is an option worth considering. However, for our final solution we opted for diversified game scenes and elements instead. Gamification elements like scoreboards, awards, achievements and progress metrics were also brought up by the respondents. According to the answers, including these elements would make the game more engaging and satisfying. Next, some of them would gladly share their achievements on social media. Hence, connecting the game with social networking platforms would also influence some users to use our gamified solutions. Regarding game graphics and sounds, diversified scenes, being able to choose from multiple avatars and importing custom music playlist was mentioned by the respondents also. Multiplayer version of the game, where one can warm up or compete with someone, according to the respondents, would make the game more appealing and usable.

Lastly, we asked the respondents to leave comments and recommendations regarding the presented prototype warm up game. We wanted to gain insight into possible features and elements expected by the respondents which could be incorporated in the game. Respondents provided us with interesting suggestions and ideas, some of which, are implemented in the second version of the game. Figure 5.25 shows the summary of responses regarding question "*Do you have any recommendations or suggestions regarding the game?*"

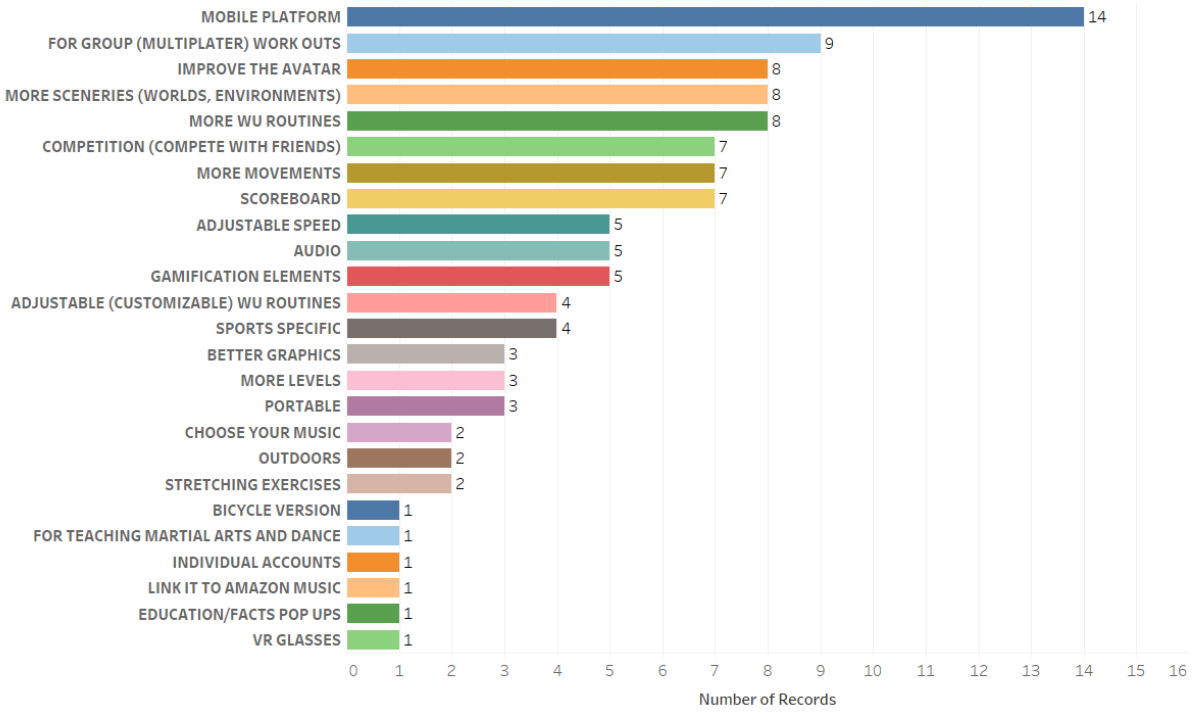

FIGURE 5.25: Aggregated answers for question: "*Do you have any recommendations or suggestions regarding the game?*"

From Figure 5.25 we observe that most of the respondents recommended designing and implementing a portable version of the game that is not constrained by any additional hardware currently required for game functioning. They suggested having a "*pocket version*" the game that can "*easily be watched on a smartphone*":

- "*Could be on an app form, everyone has a phone they can use; having arrows on the screen about which direction to use. Not as fun but just as effective.*"
- "*Well, if the whole same thing can be done on mobile, this will be a great success.*"

Furthermore, a multiplayer (group) version of the game where users can compete with others seems to be a very appealing feature most of the respondents brought up:

- "*... I actually think turning it into a competition would be cool where you have different players (and you can add your friends) and then see who completes the warm up with the most points (like Mario Kart or something similar)*"

We agree to this suggestion and hypothesize that by creating the option for competitions between athletes, our gamified system would provide users with a solid reason to keep returning to it and, in turn, help with creating a healthy habit of warming up before more strenuous exercises. By keeping track on athletes' performance on how many points have been collected during the warm up session, and also displaying these results in a form of scoreboard, our gamified solution could provide motivation to someone who might not be able to find it on its own. Most of the respondents did not like the avatar that was used in the prototype version of the game. We expected this reaction since the avatar that has been used did not have humanoid features and was represented using simple lines (skeleton). However, it replicated correctly the user's movement which was our goal with the prototype version of the game:

- "*Having a relatable character that does the workout.*"
- "*Obviously it's a prototype, but it'd be better to see a real person or game character in place of a dummy.*"

Studies have also found that having avatars that are idealized version of our self can influence how much we enjoy the game and how immersed we become. Researchers in [97] continue by saying that people also tend to "*unconsciously conform to the expectations of their avatar's appearances*". Taking this into account, we replaced the avatar in second release of the game and chose one that is more relatable and have a correct posture, as suggested by the respondents:

- "*Maybe to think over different positively looking characters with healthy right-looking postures so that a trainee's body can subconsciously copy and remember it.*"

Even though many respondents suggested a version of the game with a customizable character or with multiple characters one can choose from, the second release of the game will have only one avatar. We wanted to make the game easy to use and promptly to start. Having implemented the option with multiple and customizable character, we believe, would require more time for initial game start and, thus, increase the duration of the warm up routine altogether. We would not like for the users to spend more time designing more likeable avatars than engaging in the warm up routine. This option is, however, very appealing and will be considered for future game releases. Apart from that, many respondents recommended having more movements and exercises one needs to perform in order to complete the game that can be, in the same time, personalized and customizable (sport specific), as discussed earlier.

5.3.6 Pilot Test

The prototype has been pilot-tested with 5 student volunteers. We also conducted short interviews with the volunteers in order to collect feedback and recommendations for future releases. Overall, the responses after the warm up session using the prototype exergame were positive. Some of the collected responses were as follows:

- "*I felt like it was 30 seconds.*" - Jannik (He played for 2:20 minutes)
- "*My legs got sore, but I still want to go on.*'' - Ahmad
- "*I don't need to go to the gym today, that was enough.*" - Shweta

In the next section, an overview of the feature that will be included in the second release of the Immotion warm up exergame and are based on the results obtained through the online survey will be presented.

5.3.7 Preliminary Design Implications

Based on the answers and suggestions from the online survey, we added new features and modified exiting ones, in order to have a gamified solution for warm up that fits respondents', and presumably future users', needs the most. Since our goal was to offer a solution that can be used before every exercise and sports activity, having elements and features users expect and desire the most, we believe will make the game more appealing and, thus, more regularly used.

Game design related improvements

1. Avatar design
   The respondents argued that the avatar used in the prototype version of the game is not relatable enough. We expected this reaction since the utilized model did not have humanoid features and was represented using simple lines. Taking this into account, we replaced the avatar in second release of the game with a humanoid model that is more relatable and have a correct body posture, as requested by the respondents.
2. Different game sceneries
   According to the respondents, in the absence of the captivating visuals and sceneries, the game can become monotonous and uninteresting after a while. Thus, the scenery was redesigned completely to be visually more appealing and attractive. The game segments with empty walls and boxes were removed and the main character is placed in a jungle environment with ancient ruins and various creatures.

3. Different obstacles

   In the prototype of the game, only one type of obstacle was present. As expected, the respondents argued that the number and types of obstacles need to be increased in order to make the game more attractive. Hence, we introduced new game elements that pose as obstacles to be avoided by adding models of remains of ancient buildings, old bridges, trees, trunks, and different creatures.

4. Multiple levels

   The respondents would rather enjoy an exergame with multiple levels. Each level, according to respondents, could have different difficulty and new obstacles. This way, each level could require new movements in order to avoid those obstacles. Introducing multiple levels was an option worth considering. However, we opted for a different solution. First we increased the number of segments with different obstacles. Having done this, the set of required movements to be performed in order to avoid those obstacles also increased. Lastly, we introduced an algorithm that generates game segments randomly. This way, each warm up session became unique, in a sense that the order by which the game segments, and thus the obstacles, are presented to the user were random.

5. Achievements and rewards

   The prototype version of the game did not include any rewards or achievements. Including gamification elements like those, according to the respondents, would make the game more challenging and motivate them to take part in it more often. Taking this into account, in the second release of our warm up game, a new reward system has been introduced. Based on the number of consecutive coin collections, if not hit by an obstacle, the player will be awarded by certain amount of additional points.

6. Scoreboard

   In the second release of our gamified system, we introduced a scoreboard that displays the number of points the player collects. This gamification element is brought up by many respondents as a way of encouraging players to compete. As per various studies, the very presence of a scoreboard can often elicit the desire to play and the goal of advancing in the rankings can serve as a powerful motivator to continue [98].

7. Feedback and metrics

   The respondents also suggested that the game should monitor the correctness of the movements performed by the users and, in case of incorrect ones, inform them in a way it does not affects their performance in the game. The feedback should, also include different metrics concerning users' energy and calorie expenditure as well as which muscle groups are used in certain movements during the game. Although this suggestion is interesting, we decided not to include direct feedback or metrics during the game.

We believe that having all these metrics displayed during the game would be a distraction that will negatively impact the player's performance. Additionally, having only one motion sensor, the complete and correct mapping of the player's body and performed movement can be error prone. The only feedback the user receives during the game is in the form of rewards in case the required conditions are met. Out of the requested metrics, after the game has ended, we display the player's calorie expenditure, number of points reached and the current position on the scoreboard.

Game features related improvements

1. Customizable game settings (Avatar, Obstacles, Speed, Duration)
   The respondents would rather enjoy having a game with adjustable game elements (segments and avatar), speed, intensity, and duration. They would prefer to be able to manage and manipulate all the game's features based in their work out preferences. Nevertheless, the game segments were not made editable by the players. Our goal was to make the game easy to use and promptly to start. Having implemented the option with multiple or customizable avatars and game segments, we believe, would require more time for initial game start and, thus, increase the duration of the warm up routine altogether. The only game setting made adjustable for the second release of the game was the exergame duration. Based on the answers regarding most common warm up duration, we allowed players to select their preferred exergame length.

2. Multiplayer option
   Most respondents pointed out that the presented solution was not suitable for group (or multiplayer) exercises. Since some of the respondents often engage in group sports, they would expect that the game also includes a version where they can compete with someone while warming up, or just warm up using the game together with the group (or friend) they exercise with. This feature could hypothetically engage more categories of athletes to warm up regularly, provide users with a solid reason to keep returning to it and, in turn, help with creating a healthy habit of warming up before more strenuous exercises. However, in the second release of the game, only single player option was made available. Based on the survey results we observed that more than half of the respondents (n = 251) prefer exercising alone (56.3%). Thus, as being the majority, we decided to adapt this game feature to those athletes who prefer individual work out (sports) sessions and consider the multiplayer version for one of the subsequent game releases.

Movements and exercise related improvements

1. Increase required movements
   The respondents pointed out that only few movements were required in the game which made it one-dimensional, neglecting the warm up for arms and upper body. Introducing only limited number of segments and requiring only few movements were determined to be sufficient to present our idea of gamified warm up and assess its general acceptance. For the second release, based on the respondents' answers regarding most common movements and exercises they reported performing during warming up, we introduced new movements required to carry out in order to collect points and avoid obstacles. We believe that we captured and implemented the most common exercises and movements reported by the respondents that are, first, detectable with high accuracy using only one Kinect device and, second, accomplished easily without no prior exercise knowledge or experience.

2. Sports specific exercises
   Some of the respondents argued that the prototype game required only general movements and did not target muscle groups that are relevant for the sports they engage in. These athletes usually perform specific warm up exercises that either require prior knowledge of the exercise in order to be executed correctly, are too complex to be captured with high precision using only one Kinect sensor, or are performed in settings not suited and intended for our gamified solution (e.g. swimming, climbing). Taking into account the responses regarding types of movements the respondents usually perform in order to warm up, in the second release of our gamified system we only focused on movements that are simplistic, presumably known by the athletes, and can be captured with high accuracy using only one Kinect sensor.

3. Include stretching exercises
   Since stretching is part of most respondents' warm up routine, they also expected that the presented solution contained movements and exercises of this type. They proposed having movements that focus on the whole body stretching. However, as previously pointed out, studies have never found stretching warm ups to have any benefits in preparing our body for strenuous activity or injury prevention. Thus, the second release did not incorporate stretching exercises as required movement.

Having analysed all the results and feedback from the online survey, we incorporated the discussed changes into the final version of the exergame. The next chapter details the redesigned final version and the evaluation process performed.

Chapter 6

Overview and Evaluation of the Exergame

The overall exergame development was user centred. Based on the feedback gathered from the prototype game review, discussions with experts, and literature review, new movements have been introduced and modifications have been made to the existing design in order to make the exergame engaging, enjoyable, and more intuitive to use and interact with for the future users. This section outlines the design and development of the final version of the Immotion exergame for warm up routine guidance and motivation.

6.1 A Modular Design Approach

In order to make the exergame easily adjustable and compliant with the user requirements, in our exergame design and development we followed a modular design approach. That is, each movement (exercise) that was required from the user has been encapsulated in one distinct game segment. To put it differently, the whole game system was subdivided into smaller parts that could be independently created and then used accordingly. That way, by combining multiple segments randomly, we were able to generate a unique game map each time the user played the exergame. The end result of this approach was that our game is not constrained by one global map, but a dynamic one created on each game run. Moreover, having segments as the basic game blocks allowed us to easily add new segments that could make the game richer and the set of required movements bigger. Also, this way we could easily update or discard segments and movements users disliked or were difficult to perform. We believe this is a major feature that made our exergame scalable and extensible for future user requirements and preferences.

6.2 Discussions With Fitness Experts

During the development of our exergame, fitness and exercise experts were consulted in order to design game segments that would require movements often performed before physical activity and be effortlessly executed by the users without prior exercise knowledge.
Based on the comments received by the experts, we modified existing segments so the movements that are required to be executed are more intuitive for the user and do not require further explanation. The modular design approach allowed us to easily add segments that required movements suggested by the experts at the spot and modify existing ones. Suggestions and additional features recommended by experts were taken into account while designing all the game segments used in the final version of the exergame. Figure 6.1 captures one of our discussion with the fitness expert.

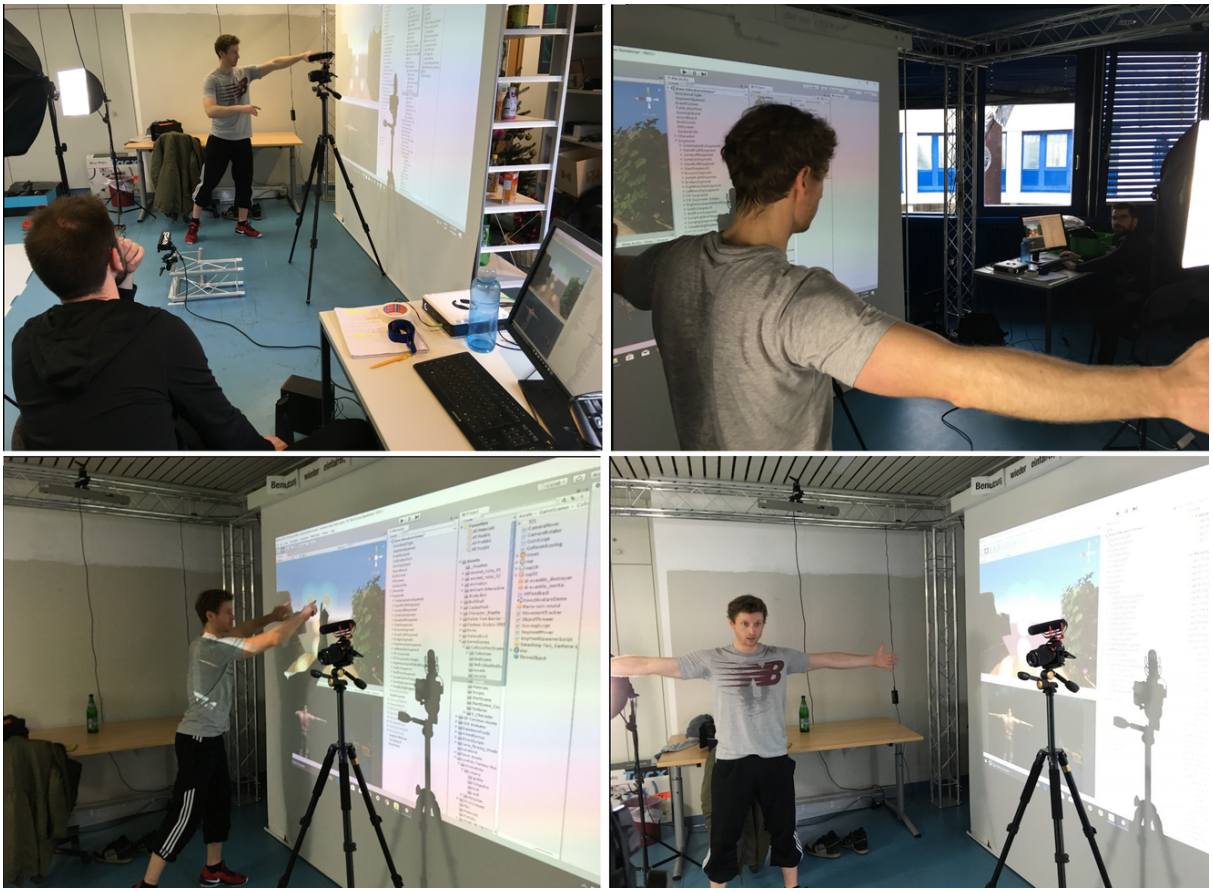

FIGURE 6.1: Exergame related design discussion with the fitness expert.

In the next sections we describe and present the redesigned exergame, the new segments introduced, as well as the movements that were required to be performed within them.

6.3 Coins Overview

For the final version of the exergame, we extended the set of coins the player can collect during the gameplay. Compared to the previous exergame version presented in Figure 5.2, three new types of coins were made available to the players. Figure 6.2 summarizes the available coin types.

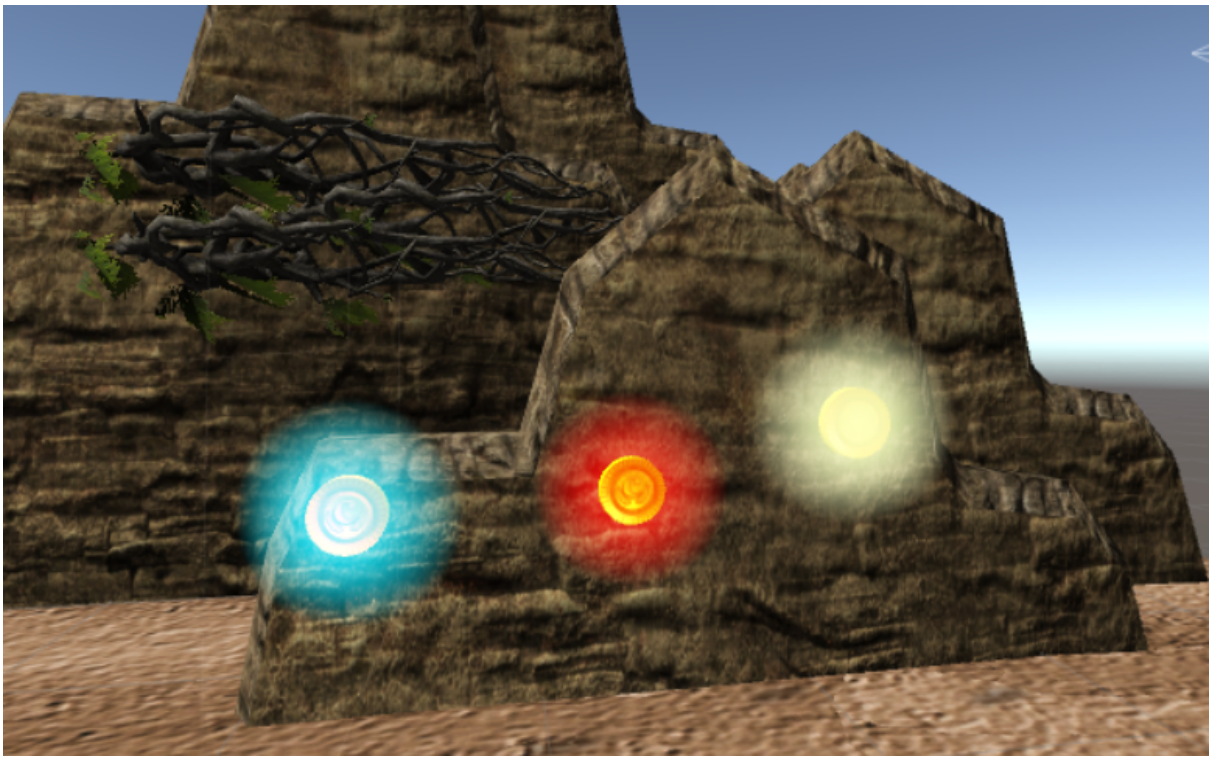

FIGURE 6.2: Coin types available in the exergame.

Each coin type presented in Figure 6.2 was worth different amount of points. How much point each coin was worth is as follows:

- Yellow coin - 1 point.
- Red coin - 3 points.
- Blue coin - 5 points.

We positioned the coins in the segments in a way the player could chose between two options. First one was to collect less points without any possibility to hit an obstacle, The second was to collect more points, but the chance to hit an obstacle and lose points, was much higher. This way we hoped to provide players the *autonomy* over their own actions and decisions as much as possible. This can, as per SDT, impact ones intrinsic motivation.

6.4 Home Window Overview

When the user starts the exergame, the *Home screen* that is depicted in Figure 6.3 is showed. Apart from starting the game, other options are available for the user as well:

- Start
- Help
- Volume
- High Score
- Quit

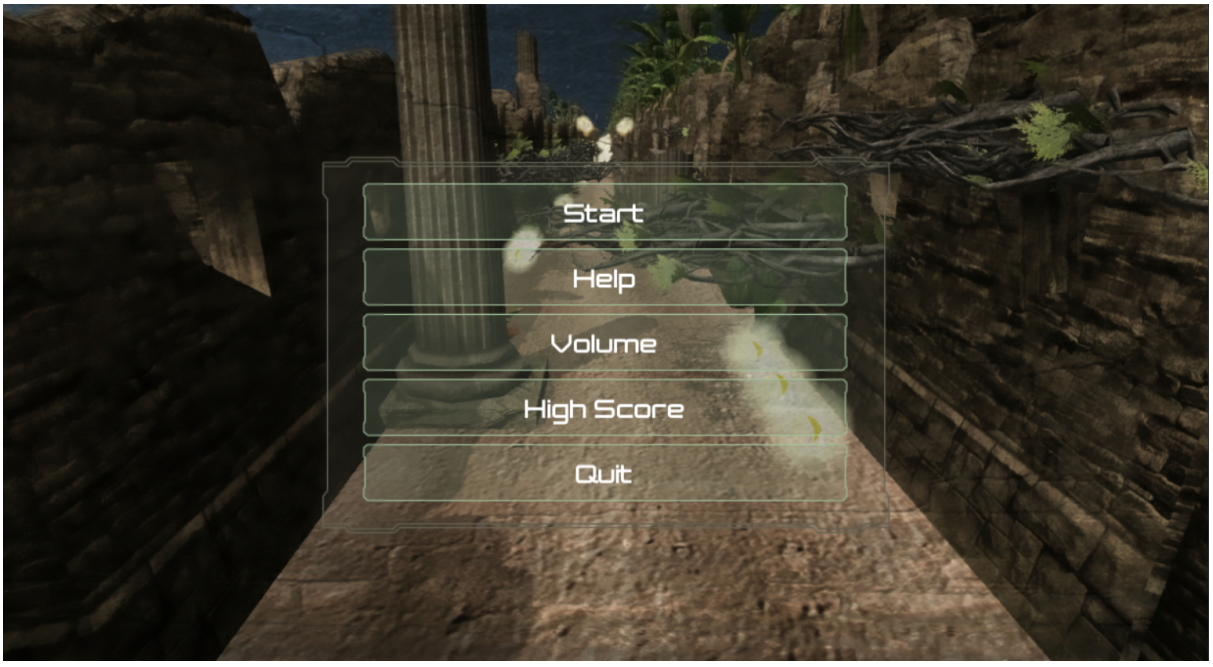

FIGURE 6.3: Home screen.

Each of the above presented options opens a new window and provides the user with certain functions. Next, the above listed options will be further detailed.

Start Menu

By selecting the *Start* button in the Home screen, the user is presented with a new screen as showed in Figure 6.4. In this step, the user needs to input a username that will be used throughout the gameplay. The username does not have to be unique. In case it already exists, at the end of the game, all the scores achieved in previous game runs with the same username will be presented in descending order by game scores as showed in Figure **??**. By selecting the Start button the exergame begins. By selecting the *Back* button, the user is directed back to the Home screen.

FIGURE 6.4: Userrname Input menu.

Help Menu

The Help menu, as presented in Figure 6.5 lets the user know how to interact with the game, change the speed of the game, and start or stop the game. It also contains contact information for error reporting and user feedback. The Back button allows the user to go back to the Home screen.

FIGURE 6.5: Help menu.

Volume Menu

The volume menu showed in Figure 6.6, gives users the possibility to modify the volume of the exergame's background music and sound effects (coins and obstacle collision sounds).

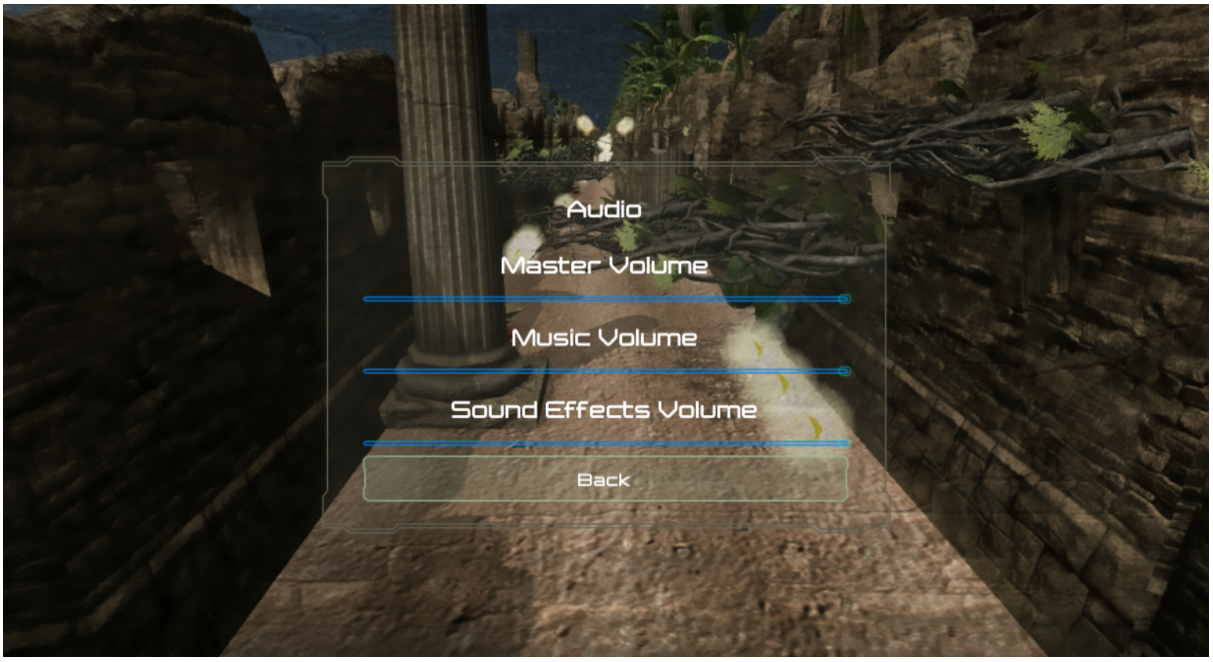

FIGURE 6.6: Adjust volume menu.

High Score Menu

The high score menu depicted in Figure 6.7 ranks the users who played the exergame based on the points collected during one gameplay. The leaderboard displays the user's rank, name, score, and duration. This is a global leaderboard and it is different than the one presented in Figure **??** since it includes all the users previously interacted with the game, their scores, and duration they played the game. Contrarily, the individual score board, displayed only at the end of each gameplay, shows the score and game duration of the user who currently interacted with the exergame. The Back button allows the user to go back to the Home screen.

FIGURE 6.7: High score menu.

Quit Menu

The quit menu button was used for ending (closing) the game.

6.5 Game Start Overview

For the purpose of tracking progress and achievements over time, users were required to input a name or username they would like to use during the gameplay. Based on the username, we displayed the user's current score and position on the leaderboard during the gameplay, and the highest scores at the end of the gameplay.

The live score board and the leaderboard are presented in Figure 6.9 and Figure 6.7. After the user set the username and pressed the Start button, a *Countdown window* as showed in Figure 6.8 is first displayed. The duration of the countdown is set to 5 seconds. We opted for this duration because it showed as the most optimal in our pilot study previously conducted with the university personal and the fitness expert. This amount of time was sufficient for the users to prepare for the upcoming exercise by moving to the correct position. In case the user was not in the Kinect sensor range at the beginning of the game, a popup information window was displayed as showed in Figure 6.10. This information window was also displayed in case the connection to the Kinect sensor failed during the gameplay.

FIGURE 6.8: Countdown window.

FIGURE 6.9: "Live score" during gameplay displayed in the left corner.

FIGURE 6.10: "Waiting for the user" popup window.

Next, an overview of the game segments and corresponding movements required to perform in each of them will be presented.

6.6 Game Segments Overview

As already pointed out, each warm up movement the user was required to perform has been represented by a game segment. Following recommendations from experts, available literature, and the previously conducted online study, the list of warm up movements the users were required to perform during the game was updated. Additionally, we introduced so called *filler* or *empty* segments. In these segments no movements were required to be performed. They were placed between regular segments where movements needed to be performed. Their only purpose was to give users a short amount of time to prepare for the subsequent game segment. By generating all the segments randomly during gameplay, each resulting game map and warm up session induced by the map were unique. Moreover, our intention was to make the exergame intuitive to use. That is, the movements should come naturally to the users and should not require additional explanation. This was the result of our iterative and user centered design approach. We designed the segments based on the movements that can help users to warm up, and not contrarily. That way, every movement induced by obstacles and coins was executed correctly and came naturally to the player without additional explanation. Figure 6.11 gives an overview of all the segments used in the exergame.

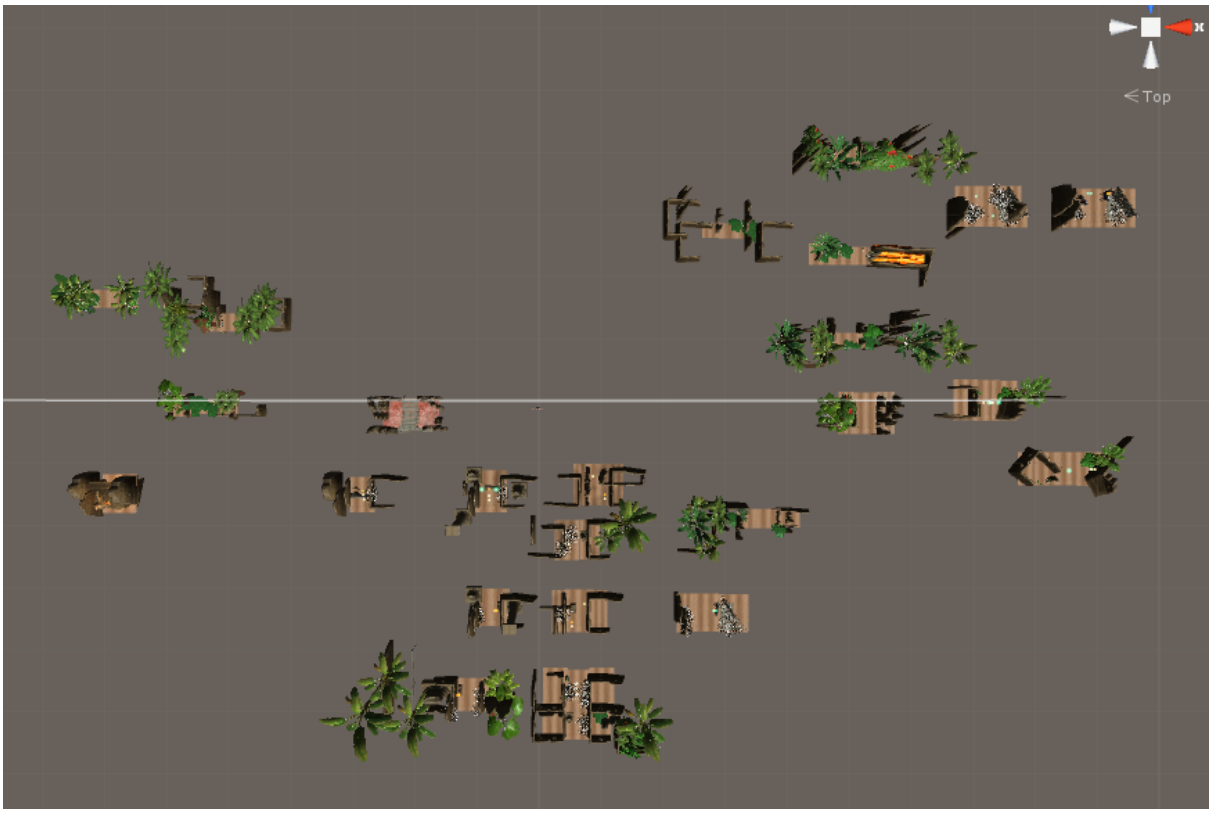

FIGURE 6.11: Overview of game segments - top view.

In most of the segments depicted in Figure 6.11, one specific movement was required to be performed. Some segments were without obstacles and were present in order for the users to prepare for the next segment (and movements). Also, segments without any obstacles were used at the beginning of the exergame. During the experiments, ten filler segments were generated at the beginning of every game run. However, this number has been made adjustable. The empty segments were placed at the beginning in order to avoid any sudden movements by the player risking injuries. Moreover, not having to perform any movements gave the player time to adjust to the gameplay and prepare for the movements. All the segments were designed to induce one of the following movement:

- Left hand up
- Right hand up
- Squat (short and long)
- Jump
- Star jump
- Left hand down to the floor
- Right hand down to the floor

Figure 6.12 shows the segment in which the user was required to move the right hand in the upper position and, in the same time, avoid the obstacle. In case the user came in contact with the obstacle, one point was substracted from the overall user's score.

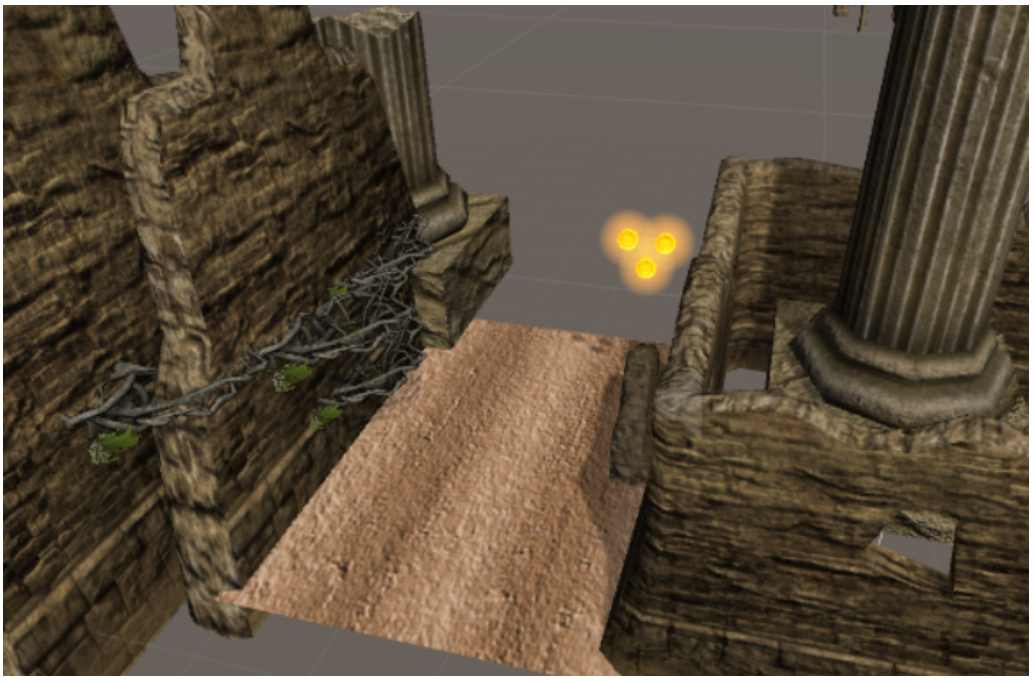

FIGURE 6.12: Right hand up segment.

FIGURE 6.13: Expert right hand up movement.

Figure 6.14 depicts the segment in which the user is required to move the left hand in the upper position in order to collect the coins. The obstacle was placed below the coins and one point is reduced from the user's overall score in case it was hit.

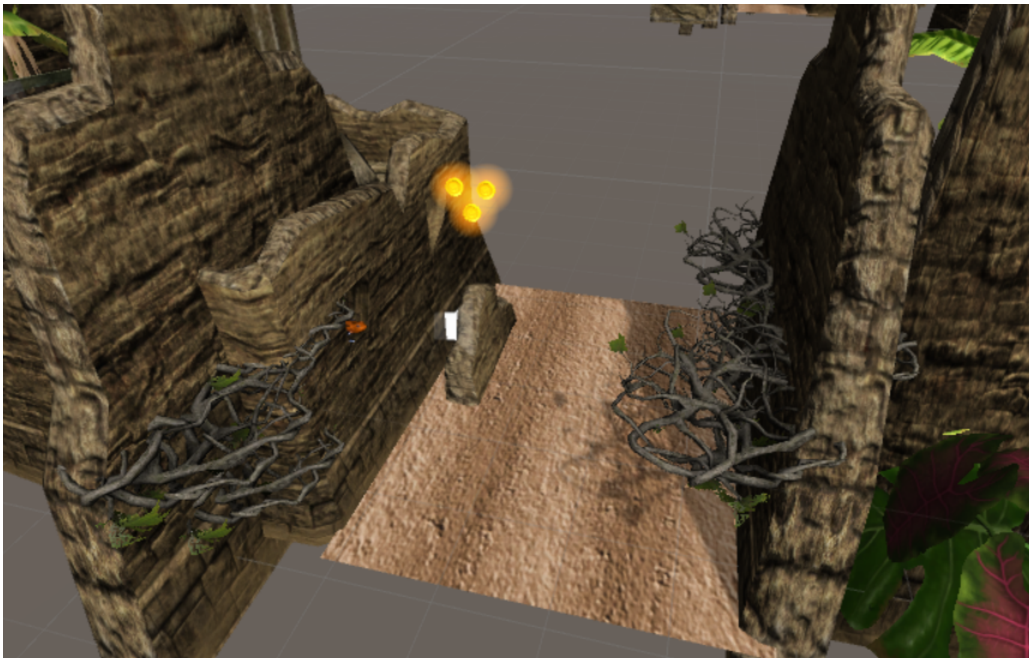

FIGURE 6.14: Left hand up segment.

FIGURE 6.15: Expert left hand up movement.

In segments presented in Figure 6.16 and Figure 6.17 similar hand movements were required to be performed. The only difference was that in these segments the user is given a choice whether to go left or right.

For instance, in Figure 6.17 player could collect four coins by moving to the right side. On the other hand, the player could also chose to go left and collect a blue coin that was worth five points. However, there was a possibility to lose points if collided with the obstacle.

FIGURE 6.16: Right hand up segment.

FIGURE 6.17: Right or Left hand up with goblin segment.

Figures 6.18 and Figure 6.19 show segments in which the player was also given an option to chose which movement to perform. Both the movements included rising hand in the upper position. The decision was left to the player. In case the player opted for the left side, the possible reward were two blue coins that were worth ten points in total. In case the player opted for the right side, the possible reward were three red coins that were worth nine points in total. However, there was a possibility to lose points by colliding with the obstacle.

FIGURE 6.18: Right or Left hand up with two wolfs segment.

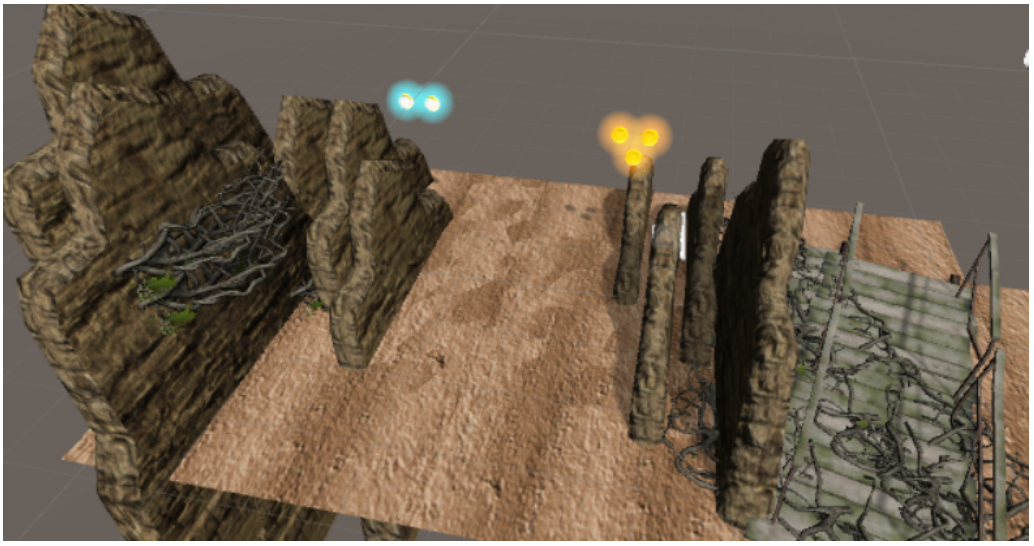

FIGURE 6.19: Right or Left hand up with walls segment.

In Figure 6.20 the player was required to move to the left and touch the floor with the left hand in order to collect the coins. Moreover, the player was required to stay in that position for a short amount of time in order to collect all the coins and than move to the right in order to avoid the obstacle.

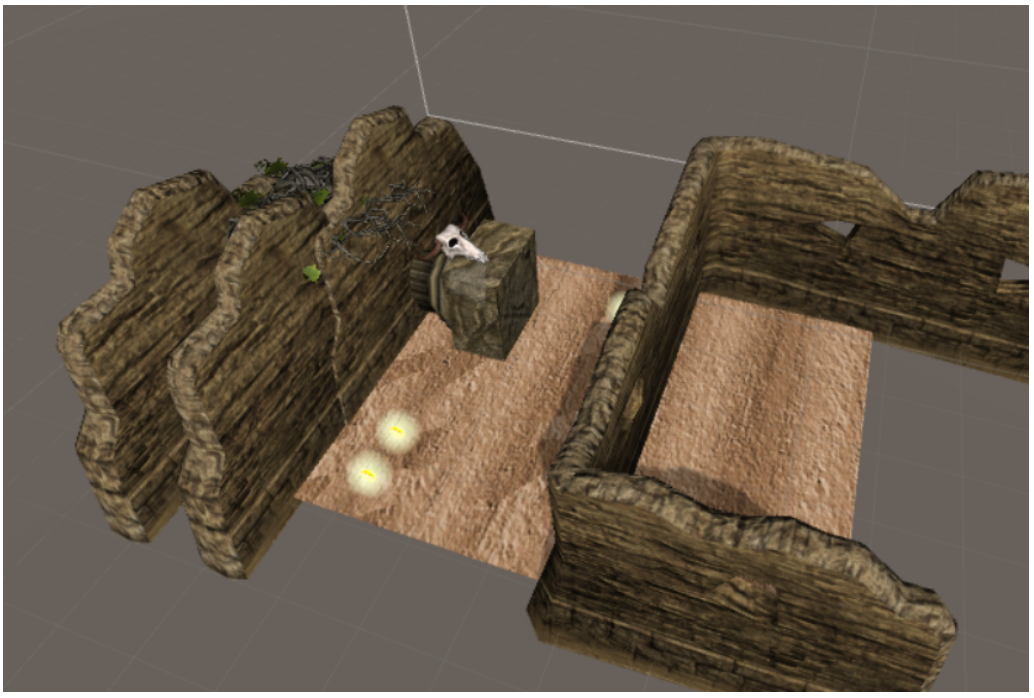

FIGURE 6.20: Move left segment.

FIGURE 6.21: Expert left hand down movement.

In Figure 6.22 the player was required move to the right and touch the floor with the right hand in order to collect the coins. As in previous segments, in case an obstacle was hit, the overall score was reduced by one.

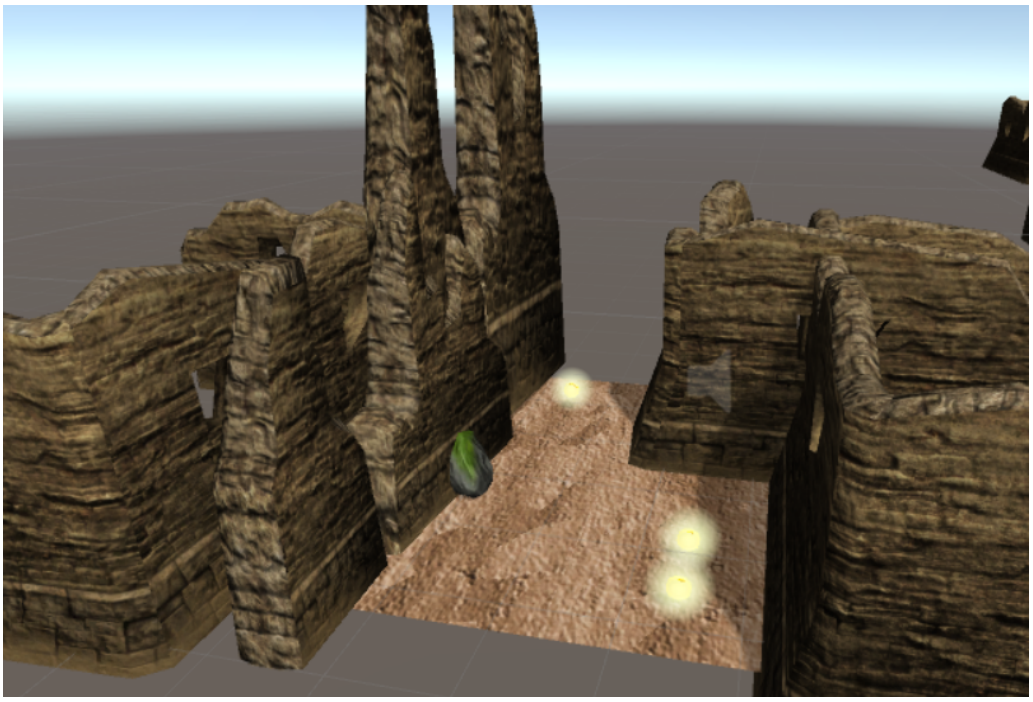

FIGURE 6.22: Move right segment.

FIGURE 6.23: Expert right hand down movement.

In the segment presented in Figure 6.24 the player was required to move right then left. Compared to the similar movements depicted in previous figures, the movements in this segment needed to be performed much faster in order to collect the coins and avoid obstacles.

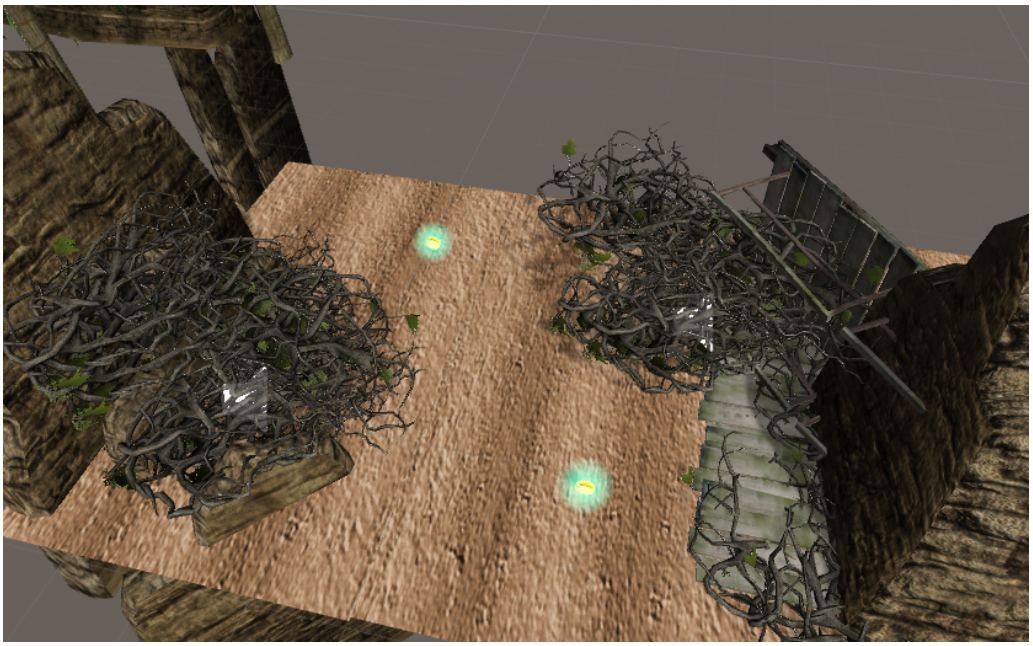

FIGURE 6.24: Move right and left segment.

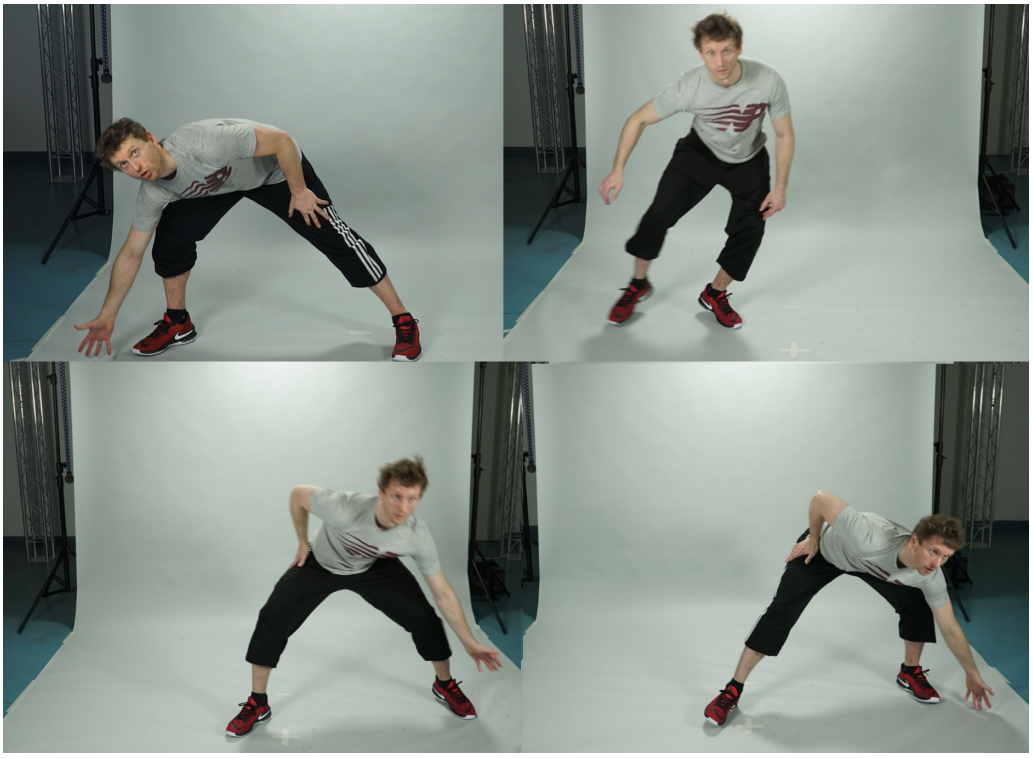

FIGURE 6.25: Expert right and left movement.

Figure 6.26 and Figure 6.27 show game segments in which the player was required to move right or left as in segments showed in Figure 6.20 and Figure 6.22. The main difference is that after moving right or left, additional squat is required in order to avoid the obstacle and collect the coins. The obstacle was placed above the the coins, and in case the player hit one of the obstacle, the overall score was reduced by one.

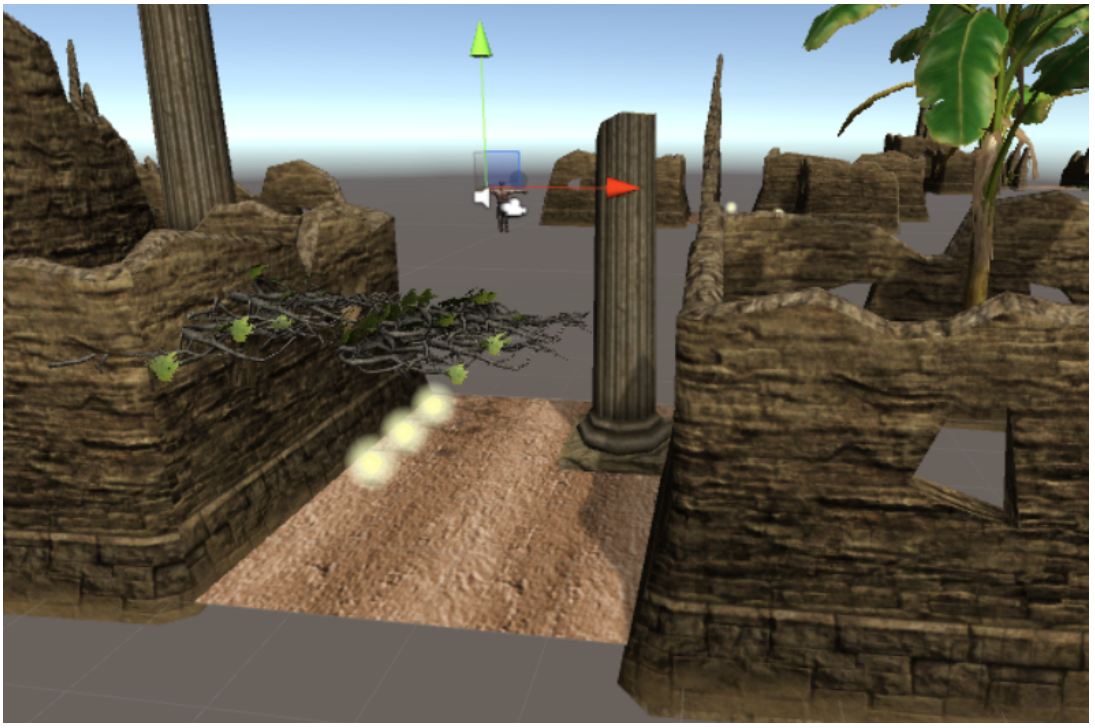

FIGURE 6.26: Move left and squat segment.

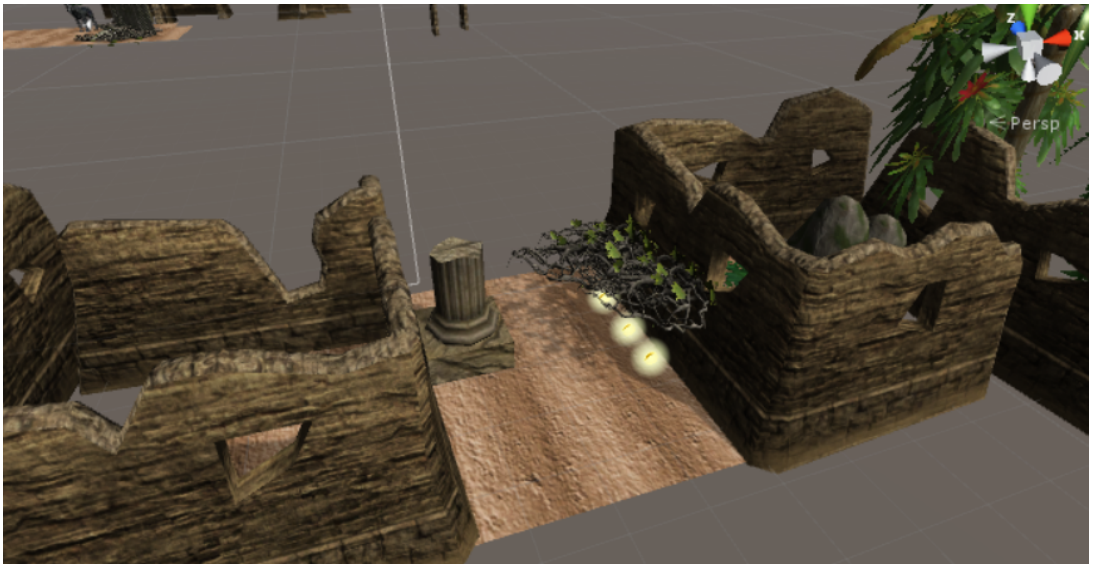

FIGURE 6.27: Move right and squat segment.

In Figures 6.28 and Figure 6.29, the player was required to perform a jump in order to avoid the obstacle and collect the coins. The obstacle depicted in Figure 6.28 was the lowest in the middle and in case it was hit, the player's total score was reduced by one point. The player was presented with a choice of collecting additional blue coins with the jump. The blue coins were positioned in a way that required higher jump and placing both hand in the upper position in order to be collected.

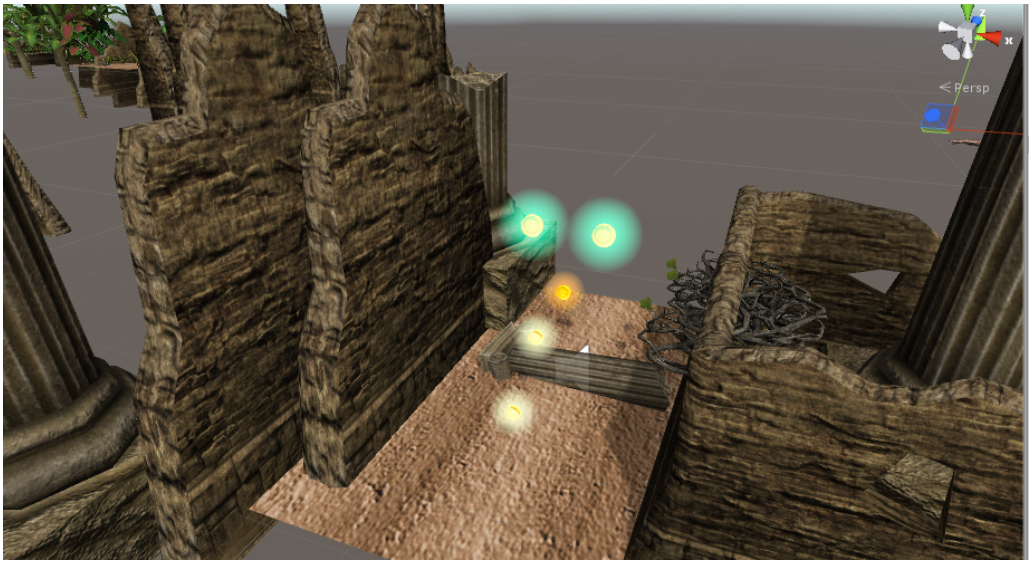

FIGURE 6.28: Jump up segment.

Compared to the movement required in the previous segment, the one needed to be executed in Figure 6.29 did not require additional hand movement.

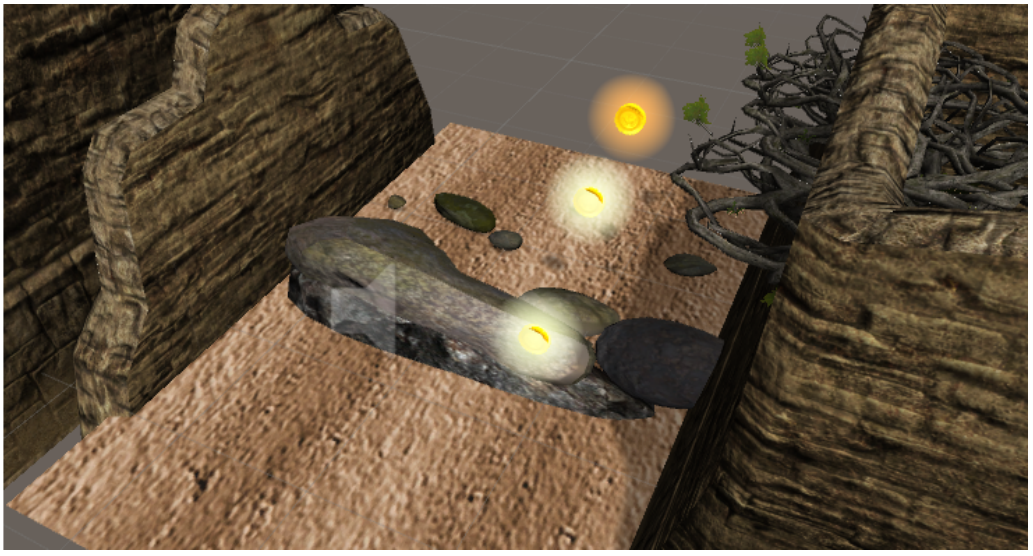

FIGURE 6.29: Jump up segment.

Figure 6.30 depicts a game segment where the player was required to perform a *star* jump in order to collect all the coins.

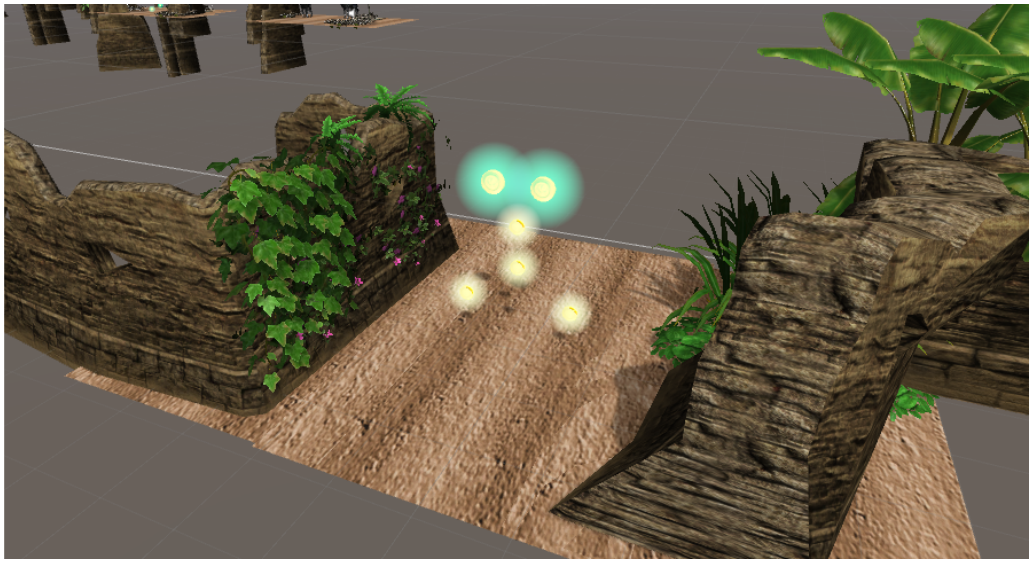

FIGURE 6.30: Star jump segment.

FIGURE 6.31: Star jump movement.

Figures 6.32 and Figure 6.34 depict game segments in which the player was required to perform a squat in order to collect coins and avoid the obstacle. In case the user hit the obstacle placed above the coins, the overall score was reduced by one point.

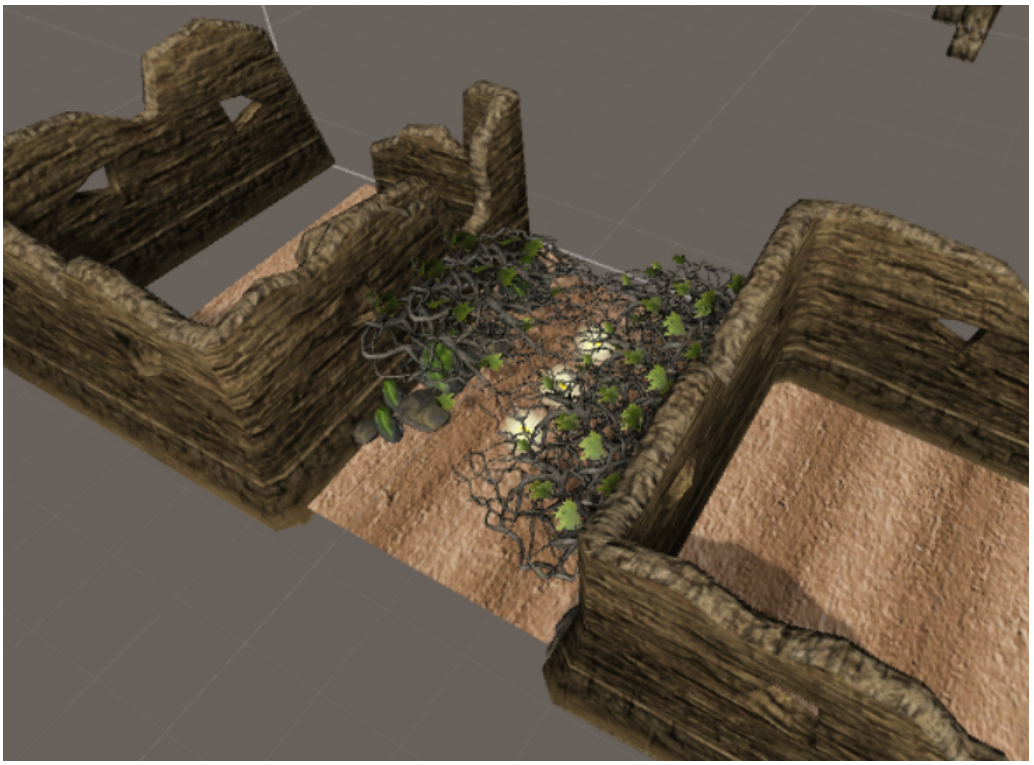

FIGURE 6.32: Squat segment.

FIGURE 6.33: Squat long segment.

FIGURE 6.34: Squat movement.

Figure 6.35 is one of the filler segments used for the player to prepare for the next movement. However, in case the player did not use the bridge and came in contact with the walls or lava obstacles, the overall score was reduced by one point.

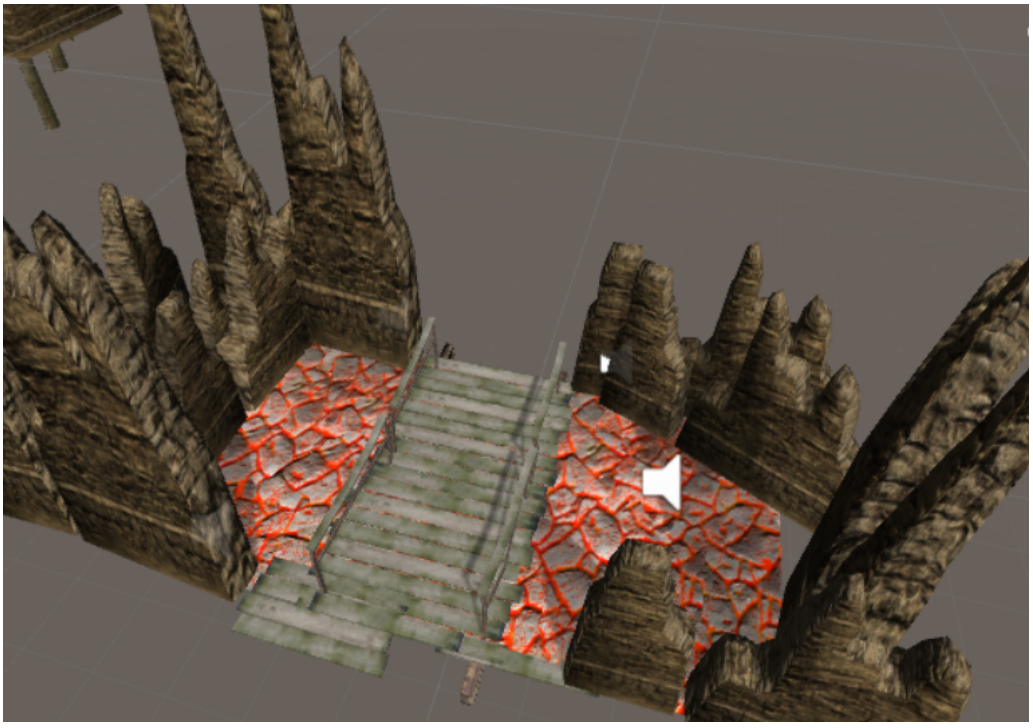

FIGURE 6.35: Bridge segment.

Figure 6.36 depicts the rest of the filler segments that are placed at the beginning of the game and in between segments with obstacles in order to give players enough time to prepare for the subsequent movement.

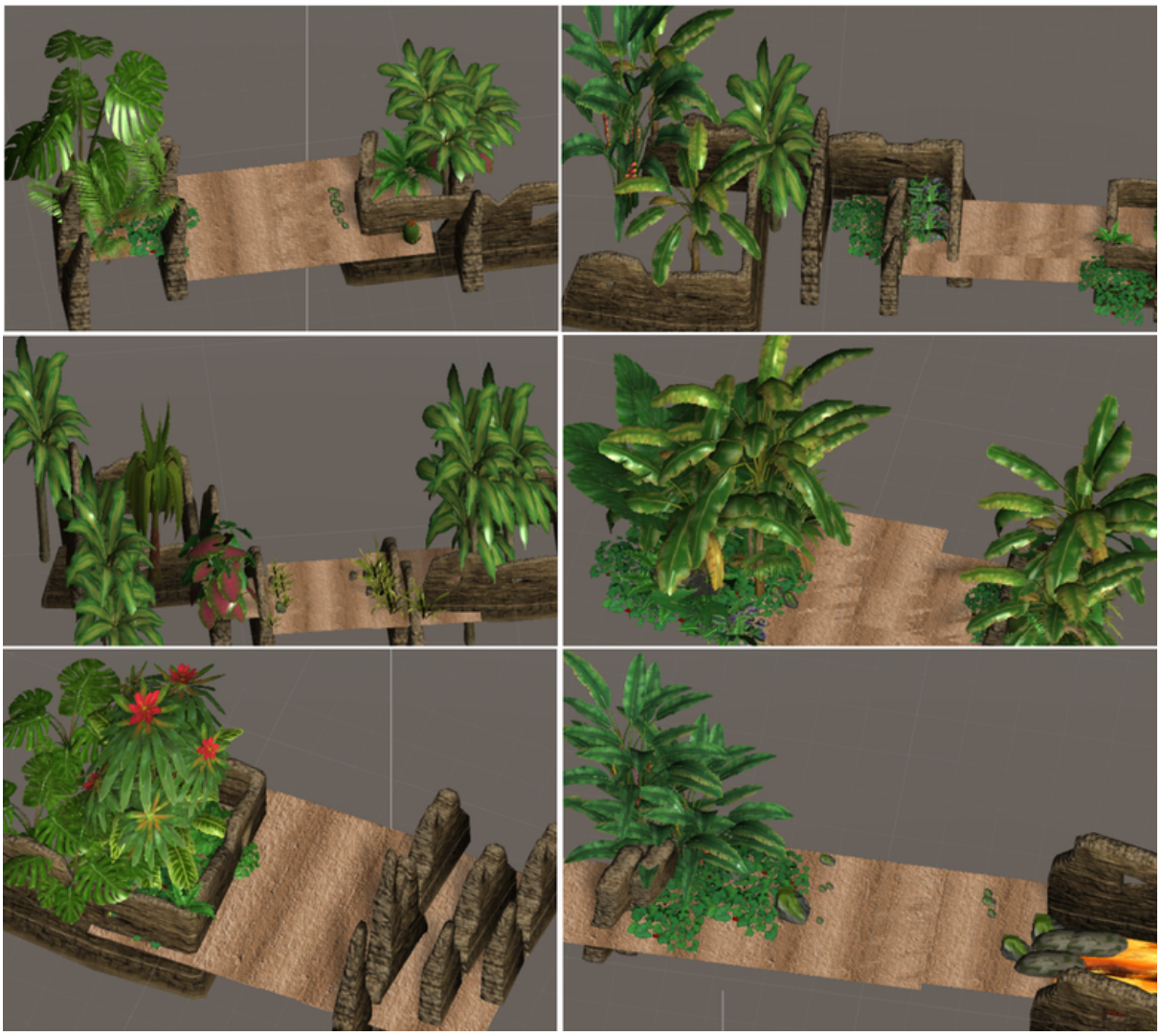

FIGURE 6.36: Filler segments.

To conclude, by placing the obstacle and coins in a specific position, our intention was to indirectly promote exercise through the gameplay of repeatedly performing warm up related movements chosen during previous development phases and discussions with fitness experts. We ought to design game segments that are engaging for the player so we immerse the exergame players sufficiently so that their focus is shifted from the discomfort and exertion of the exercise towards the enjoyment of the experience.

6.7 Game End Overview

We implemented two approaches for ending the game. First one allowed the player to choose from a set of recommended warm up duration at the beginning of the gameplay. That is, the exergame ended after the selected time interval. The second was to end the exergame when the player felt warmed up enough for the subsequent physical activity. For the purpose of the user study, we utilized the second approach. This gave us information about the most common duration of the warm up sessions and later allowed us to compare it with the reported ones from self reported surveys.
When the game ended, the *Individual scoreboard* was presented to the player. The scoreboard is depicted in Figure 6.37.

FIGURE 6.37: Individual end scene.

Based on the player's username we displayed all the previous scores. The scores were displayed in descending order by the points achieved during each game run. The player was also presented with the duration each game lasted and the personal best score. By selecting the *Back to main menu* button, the player could go back to the Home screen.

Chapter 7

Study Design

The main goals of this thesis were to:

1. develop an exergame which can be used for warm up routine before more strenuous physical activity, and
2. evaluate its effectiveness in terms of guiding the user through the process of warming up.

In this chapter we outline the research framework, detail the research methods, and discuss the obtained results.

7.1 Description of the Experiment

This section describes the evaluation of the second version of the Immotion exergame. Our study follows a between–subject design with warm up activity (performed while interacting with the exergame and performed without interacting with the exergame) as the independent variable. During the experiment, data has been logged, surveys have been conducted, and interviews undertaken. Similarly to the evaluation of the prototype exergame (Chapter 5), the obtained results are analysed in order to determine to which level our proposed solution was effective in the given context and whether it offered a solution to the problem.

7.1.1 Introduction and Goals

The first study evaluated the prototype exergame. Based on the results obtained, comments, and suggestions, the prototype exergame has been modified to better suit the needs of its future users.

The primary goal of the second study was to investigate whether our modified exergame solution can be used as an interactive guide for individuals who do not know how to perform warm up routines. In addition, we examined if the exergame can be used as a solution that motivates individuals to warm up before physically more demanding exercises, and provides an enjoyable game, as well as play, experience. Taking this into account, the research questions we address in this study are as follows:

1. **RQ1: Evaluation of effectiveness** - How effective our proposed solution is in guiding the user through the warm up routine compared to the guidance offered by classic (traditional) methods?
2. **RQ2: Evaluation of perceived usefulness and ease of use** - How useful and easy to use our proposed solution is?
3. **RQ3: Evaluation of the usability** - How usable our proposed solution is?
4. **RQ4: Evaluation of the game experience** - How enjoyable and entertaining our proposed solution is?

In order to evaluate the effectiveness, perceived user experience, usefulness, and usability of our exergame solution in the given context, the user base is divided into two groups: *experiment group* and *control group*. The first, experiment group, interacted with the exergame directly. Contrarily, the control group was presented with the video of a coach (professional) who guided the participant through the warm up routine. This division allowed us to infer the influence of our gamified solution, as well as, to assess the main differences in completing the required activities between the two user groups.

7.1.1.1 Hypotheses

Based on the research questions outlined in the previous section, the following hypotheses were established to be tested:

- H_1: The exergame itself is sufficient for guiding the player through a proper warm up procedure.
- H_2: After the warm up routine is completed by interacting with the exergame, participant's Range of Motion (ROM) is increased.
- H_3: Participants had a more positive perceived warm up experience when using the exergame compared to the participants not using the exergame.
- H_4: The duration of the warm up session is significantly longer for the participants in the experiment condition.

7.1.1.2 Apparatus

The experiment was conducted in the laboratory room in DFKI. The laboratory with the hardware used in the experiment is presented in Figure 7.1.

FIGURE 7.1: The laboratory where the experiment has been conducted.

The following equipment has been used during the experiment:

- Kinect for Xbox One (2.0 2013) motion sensing input devices by Microsoft used for movement detection and controlling the exergame avatar.
- Kinect for Xbox One (2.0 2013) motion sensing input devices by Microsoft used for recording the experiment.
- PC running the game engine.
- Projector used to display the game (video) on the wall in front of the participant.
- Microsoft Band used for gathering skin resistance data.
- Polar H7 Bluetooth Heart Rate Sensor and Fitness Tracker for hear rate and respiratory rate monitoring.
- Camera for taking photos of participants' facial expressions during the warm up procedure.
- Goniometer used for measuring participants' ROM.

Both Kinect motion sensors have been placed in front of the display panel facing the participant playing the exergame or following the video. The participant was instructed to keep at least 2 meters distance from the sensor during the gameplay. This distance was the most optimal in order for the system to function properly in terms of skeleton tracking. We used a projector in order to display the exergame and video to the participants that was placed above the user so it did not interfere with the game flow.

7.1.2 Methods

In this section we outline the methodology adopted for the Immotion exergame evaluation. For this purpose we utilized a between-group design with two groups of subjects. We opted for this approach since it gives direct input on how real users use the system.

7.1.2.1 Participants

The study has been conducted on Wednesday 28th March, 2018 and Thursday 29th March, 2018 in DFKI. All participants were students from Saarland University. The participants reported no physical impairment at the time of participating in the study. For recruiting participants, posters were distributed in print, and sent through social media and email (Appendix X). Each participant was given 10 euros cash for taking part in the study. All of the participants were amateur athletes who engage in some physical activity on average 4 times per week. For the study we particularly targeted individuals who exercise in gym or fitness centers and often avoid preforming warm up exercises before more strenuous physical activity. All participants were required to report to the laboratory in gym based clothing, preferably shorts and t-shirt, and all of them performed the required tests in the same location using the same equipment. Before the study, each participant signed a consent form.

7.1.2.2 Conditions

First 10 participants who applied for the experiment have been accepted. These participants were sent a pre-test questionnaires (BSA-F, PARQ, and a Demographic questionnaire) that needed to be completed before coming to the experiment. Based on the answers given, the participants were assigned to the control or the experiment group. Each assigned participant took part in a single test session one hour in duration. During this session, all the participants performed one warm up session, after which they completed a set of questionnaires.

Two conditions were evaluated:

1. Warming up with the exergame guiding through the warm up procedure, projected on a wall in front of the participant.
2. Warming up with a video of a professional (coach) guiding through the exact same warm up procedure as induced by the exergame, projected on a wall in front of the participant.

Depending on the group, each participant performed exercise that represent one of the condition.

7.1.2.3 Control and Experiment Group

The participants were assigned to the control or experiment group based on the answers provided in the self-reported questionnaires that were sent to them before the experiment. The surveys assessed participants' perceived physical fitness level, warm up preferences, and previous exergames experience.

7.1.2.4 Measures and Metrics

Two separate sets of questionnaires were administered, one prior to the experiment session and one post the session in order to gather self-reported user perception data. The pre-test questionnaires focused on participants' demographic information, overall physical and psychological abilities, hours spent on exercise, frequency and activity of warm up procedures, extent of video gameplay, and reason for playing. The pre-test questionnaires were as follows:

- *Health status.* The current health status of the participants has been assessed via the Physical Activity Readiness Questionnaire (PARQ), which consists of seven dichotomous items [99]. The individual response patterns were used in order to assess if participants were physically able to perform the warm up session.
- Demographic survey with questions regarding warm up preferences and previous exergame experience.
- *Physical activity screening.* Pre-study physical activity levels have been assessed with a standardized questionnaire Bewegungs und Sportaktivität Fragebogen (BSA-F) [100]. Participants were instructed to indicate for how many minutes per week they performed everyday physical activities (e.g., taking the bike to work; taking a walk) in average during the last four weeks.

The second set of questionnaires have been administered after the completion of the warm up procedure. In these questionnaires participants' level of exertion, emotional state, and game experience have been assessed. The questionnaires were as follows:

- *Perceived exertion.* For assessing the perceived exertion of the warm up session, the BORG rating of Perceived Exertion (RPE) has been utilized [101]. The perceived exertion reflects how difficult and strenuous the performed warm up exercise feels to the participants, combining all sensations and feelings of physical stress, effort, and fatigue.
- *Emotional state.* The pleasure, arousal, and dominance associated with a person's affective reaction to a wide variety of stimuli has been assessed with Self-Assessment Manikin Scale (SAM) [102].
- *Enjoyment of the physical activity.* To test the enjoyment of the physical activity performed, in this case the warm up procedure, the Physical Activity Enjoyment Scale (PACES) has been used [103].
- *System usability.* For assessing the exergame's instrumental qualities (e.g. controllability, effectiveness, learnability), the System Usability Scale (SUS) has been used.
- *Enjoyment of the play.* In order to measure the play enjoyment and experience, the Play Experience Scale (PES) has been utilized [104].
- *Bartle's player type.* In order to determine participants' personality types based on their preferred actions within the game, we utilized Bartle's framework and questionnaire [85].

During the experiment, the following metrics were collected from each participants:

- *Range of motion.* The participants' ROM has been measured before and after the warm up routine using goniometer.
- *Heart rate and Respiratory rate.* The participant's heart rate data has been captured and the measured during the warm up procedure using Microsoft Band.
- *Skin resistance.* The participant's skin resistance data has been captured and the measured during the warm up procedure using Microsoft Band.

The warm up routine performed by the participant has been recorded using a second Kinect sensor for further analysis of performed movements.

7.1.2.5 Tasks

In order to interact with the gamified system, the participants in the experiment group were required to perform a set of general movements. By performing these movements, the participant controlled the game avatar and, by doing so, attempted to avoid obstacles and collected coins. Based on the data and feedback gathered from the first study, we limited the movements the participants needed to perform in the exergame. That is, only movements that are detectable with high accuracy using only one Kinect device and simplistic enough to be accomplished easily without prior exercise knowledge or experience were required to be executed by the participants. These movements were:

- right hand movement up,
- left hand movement up,
- jump right,
- jump left,
- jump up,
- star jump, and
- squat.

Participants who were in the control group were required to perform the same set of general movements. However, they had to follow a video and did not interact with the exergame directly. The video was a recording of a professional (coach) who guided the participants through the warm up routine. We have recorded the warm session with the coach before the study. The movements the coach executed have been induced by interacting with the exergame. Thus, by following the video, the participants in the control condition executed the same movements in the same order as the participants in the experiment group who interacted with the exergame. This means that indirectly they were playing the exregame too.

7.1.2.6 Procedure

The study protocol was reviewed and approved by an institutional ethics committee. For data collection, we used a paper and pencil as well as *Google forms* questionnaires. Before the experiment, the lab environment has been set up. The Kinect sensor was placed in a correct position and turned on. The PC running the software was started and the projector is enabled. In each session only one participant was present and guided by the researcher.

The activities each participant followed were:

- The participant completes the preliminary survey.
- The researcher explains the sensors and tools that are required for the experiment, after which the participant puts them on.
- After the researcher confirms that the sensors are placed in a correct position, we start recording heart rate data.
- The researcher measures the participant's ROM before starting the warm up procedure. The following ROM's are assessed:
  - Left and right shoulder rotation
  - Left and right shoulder extension
  - Left and right hip flexion
  - Left and right hip extension
- After the measurements are collected, the participant rests while the researcher explains what is required from the participant.
- The researcher gives a general explanation on the benefits of a proper warm up routine before physically more demanding exercise.
- The participant moves to the spot marked by the researcher.
- The researcher starts recording the session.
- The warm up procedure begins:
  - If this participant is part of the experiment condition, the game begins with the *Start scene*. The researcher inputs the participant's name and presses the *Start* button. After 5 seconds, the game proceeds with scenes in which the participant is required to perform specific movements in order to avoid obstacles and collect coins. The duration of the game is not fixed and it is played up to the point when the participant feels warmed up enough.
  - In case the participant is part of the control group, the video that displays a coach who instructs the participants which movements need to be performed. As with with the sessions in the experiment group, the duration of the warm up is not fixed and the video is played up to the point when the participant feels warmed up enough.

- After finishing with the warm up routine, the participant takes a rest. The data collection is stopped. During this period the sensors are removed from the participant.
- Researcher assesses the ROM of the participant.
- The participant completes the post-test surveys .

7.1.3 Limitations - Threats to Validity

Our participant sample has an unbalanced gender ratio and a limited age range, which represent a limitation for the study results. Moreover, the arms of the standard goniometer that has been used for measuring participants' ROM were not longer than 12-inches which made it difficult to accurately pinpoint the exact landmark needed for measurement. Furthermore, our results are based on a single experiment only. Hence, the longitudinal effects of the exergame usage cannot be predicted.

7.2 Results

Our subject group included 10 individuals, of which 2 were female and 8 were male. Participants were on average age $M = 26.7$ years old ($SD = 1.77, x_{max} = 30, x_{min} = 24$), with different levels of education, such as Bachelor's degree (n = 4) and Master's degree (n = 6). Two participants reported to exercise 7 to 8 times per week and only 1 participant 5 to 6 times per week. The majority of the participants exercise 1 to 2 times (n = 3) or 3 to 4 times (n = 4) per week. The duration of the sport or fitness activity for most of the participants was between 1 and 2 hours long (n = 8). Only 2 participants reported engaging in sports activity with duration less than 1 hour. The most common exercises the participants reported to engage in were:

- Anaerobic exercise - sit-ups, pull-ups, push-ups, squats, and weight lifting (n = 8).
- Team sports - football, basketball, cricket, handball, etc (n = 4).
- Running outdoors, running on treadmills, and doing yoga (n = 3); cycling and jogging (n = 2).

The majority of the participants (n = 7) engage in physical activity alone, while only 3 participants enjoy sports activities performed in a group. Out of 10 participants, 3 reported not engaging in warm up exercises before sports sessions. The most common reasons reported by the respondents were time constraint, the monotonous and tiresome nature of the warm up procedure, how the warm up procedure represents an insignificant and negligible activity, and lastly, that no one warms up either.

Regarding duration of the warm up session, 6 participants reported spending less than 5 minutes for warming up, while 4 participants reported spending between 5 and 10 minutes on this preparatory activity.

FIGURE 7.2: Participants during the experiment performing the warm up procedure.

Out of all the participants, 7 stated that they engage in sport specific warm up, whereas 3 reported engaging in general (non-specific) warm up exercises. Half of the participants (n = 5) stated that they do not enjoy warming up in a group. When inquired about preferences regarding warming up when given instruction, 6 participants stated they prefer warming up when given instructions, while 4 participants stated they do not prefer warming up when given instructions. The engagement in playing video games varies among the participants: 1 plays video games daily, 1 few times per month, 1 once per month, 2 once a day, 3 few times per year, and 4 once per year or less. The most common game types among participants were racing (n = 5) and sports games (n = 4). In addition, when inquired about their previous experience with Microsoft Kinect games, only 1 participant reported having a lot of experience with games in this area. The rest of the participants reported having either non or some experience with Kinect related games.

In the following subsections we present and discuss the results obtained from various questionnaires the participants completed, as well as, from the metrics that have been tracked and analysed during the warm up procedure.

7.2.1 Range of Motion

ROM has been assessed for each condition before the warm up session and immediately the participants completed the procedure. For taking the measures a plastic goniometer with 1 degree increments has been utilized. The average ROM values with standard errors for each condition are presented in Figure 7.3 and Figure 7.4. The detailed table with individual values for each measured joint can be found in Appendix XXX.

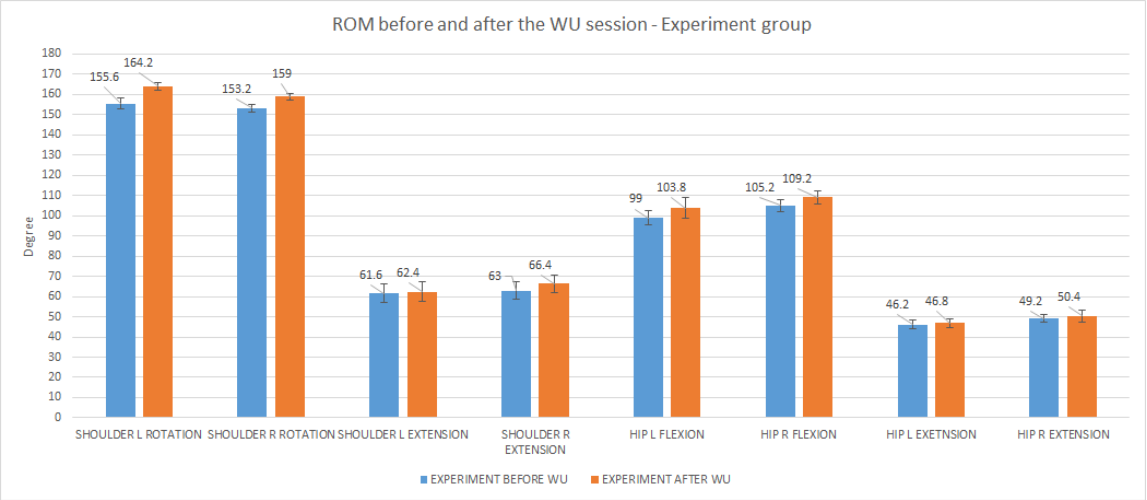

FIGURE 7.3: Summary of ROM results for the Experiment condition.

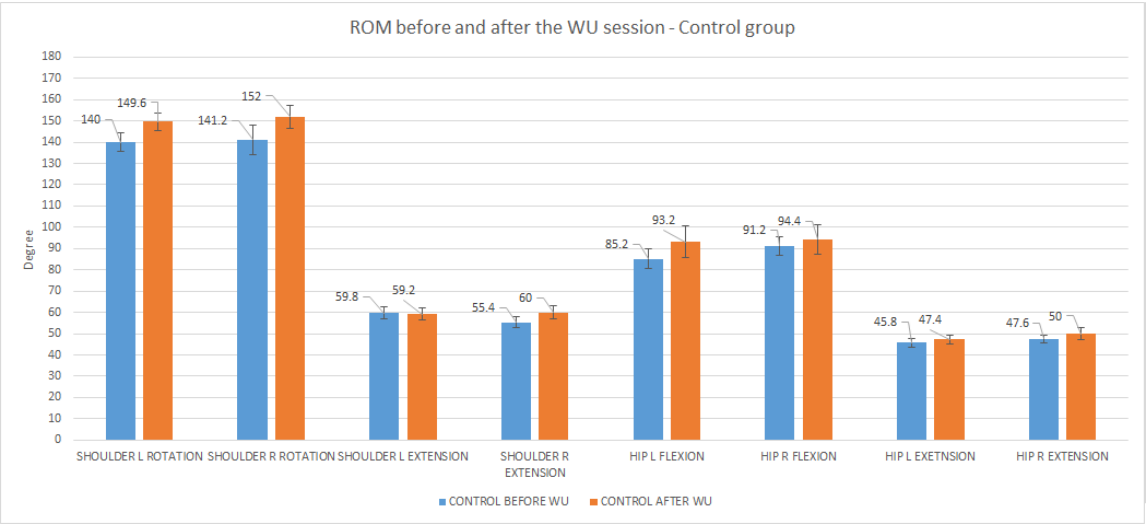

FIGURE 7.4: Summary of ROM results for the Control condition.

We observed that the average values after the warm up session for all measured joints were higher in each experiment condition. These increased measures imply that our exergame solution, as traditional warm up procedures, positively affects one's ROM. A paired-samples t-test for independent means was also conducted to compare the obtained ROM results after the warm up session in experiment and control condition was completed.

The results showed that there was no significant difference in the scores between conditions at $p = 0.05$. These results suggest that even though there are increases in ROM after performing warm up session by interacting with our exergame solution, the increase is analogous to the increase in ROM after traditional warm up session.

7.2.2 Warm Up Duration

The duration of the warm up session has been measured from the game or video start until the moment the participant stopped with the warm up session. The participants have been informed to play the game or follow the video instructions as long as they usually spend on warm up session before some physically strenuous activity. As already pointed out, the exergame was designed with an option for the participant to choose the most desirable warm up duration. However, during the study, this option has been disabled, and the participant could interact with the game and follow the video as long as they felt adequate. The average warm up duration for the experiment condition was $M = 800.4$ seconds ($SD = 205.4, x_{max} = 1122, x_{min} = 616$), whereas for the control condition was $M = 444.2$ seconds ($SD = 94.2, x_{max} = 576, x_{min} = 345$). The results with standard errors for each condition are presented in Figure 7.5. Based on the results depicted in Figure 7.5 we observed that the average duration of the warm up session for the participants in the experiment group was significantly higher compared to the duration of the warm up session for the participants in the control group. That is, interacting with the exergame positively influenced the duration of the warm up session for all the participants in the experiment condition.

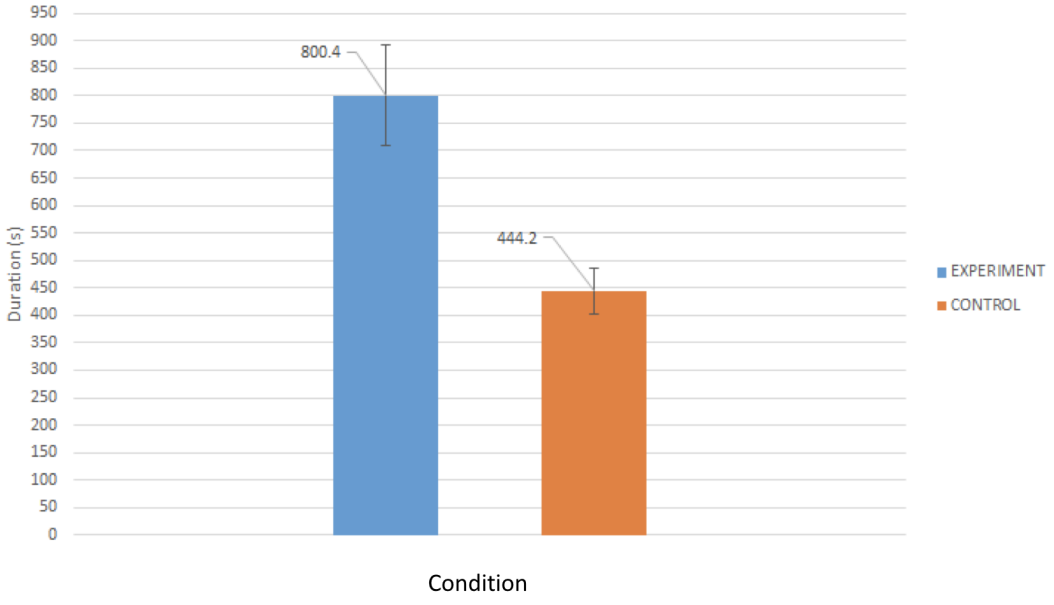

FIGURE 7.5: Average warm up duration with standard errors per condition.

An independent-samples t-test was conducted to compare average warm up duration in experiment and control conditions. There was a significant difference in the scores for experiment (M=800.4 SD=205.4) and control (M=444.2, SD=94.2) conditions; t(8)=2.89, p = 0.20. These results imply that our exergame does have an effect on warm up duration. That is, the warm up duration increases when performed by interacting with our exergame solution.

7.2.3 Heart Rate

The heart rate data has been captured and monitored using Polar H7 Bluetooth Heart Rate Sensor and Fitness Tracker in order to determine the exercise intensity. The heart rate has been measured from the beginning of the warm up session until the moment the participant declared being warmed up enough for a subsequent hypothetical physical activity. The average maximum heart rate per participant that is relative to the maximum heart rate computed for each participant based on age, resting heart rate, and heart rate reserve with standard errors is presented in Figure 7.6 ($M_{exp} = 0.919$, $SD_{exp} = 0.043$, $M_{con} = 0.84$, $SD_{con} = 0.050$). The bars presented in Figure 7.6 are based on the maximum heart rates calculated for each participant using *Karvonen method* [105] and obtained by each participant during the warm up session. Additionally, the average maximum heart rate for the participants in the experiment group was $M_{exp} = 174.20$ ($SD = 7.01, x_{max} = 186, x_{min} = 170$). The average maximum heart rate for the participants in the control group was $M_{con} = 158.8$ ($SD = 10.06, x_{max} = 169, x_{min} = 144$). From Figure 7.6 is evident that the participants in the experiment condition reached higher relative heart rates based on age groups, compared to the participants in the control condition.

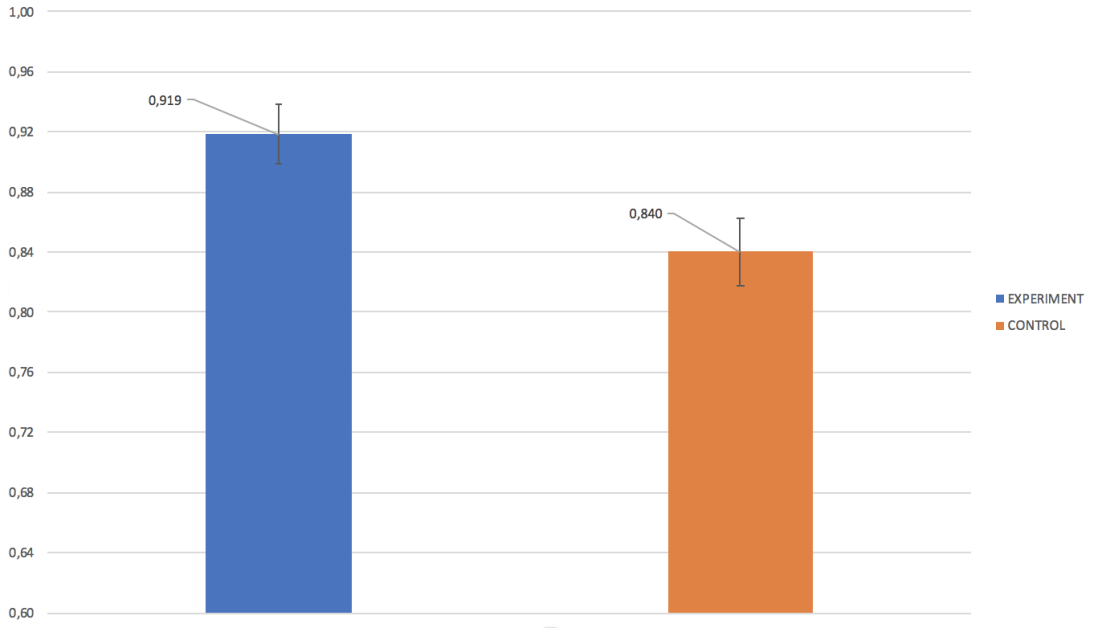

FIGURE 7.6: Average Maximum Relative heart rate per study group.

The individual heart rate data for each participant is depicted in Figure 7.7 [1]. It can be observed, as previously pointed out, that the participants in the experiment group who interacted with the exergame solution, reached higher level of heart rates during the warm up session compared to the participants in the control condition. Furthermore, from Figure 7.7 is evident that the duration of the warm up session for the participants in the experiment group was significantly longer too.

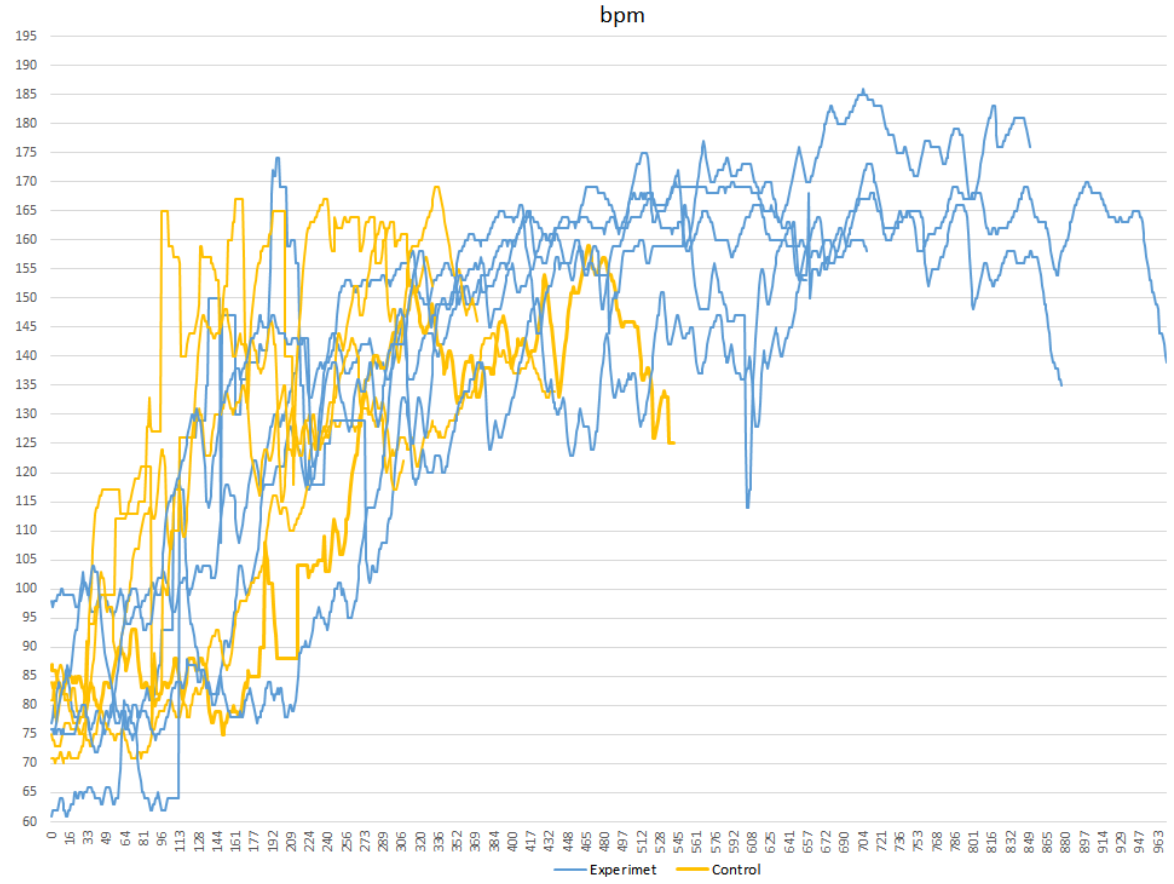

FIGURE 7.7: Heart rate data for each participant.

Lastly, we calculated the zones of the target heart rate (T_{HR}) for each participant that is based on the maximum heart rate. A number of formulas are used to estimate THR_{max} [106]. Researchers in [105] proposed the following formula for calculating THR_{max}:

$$THR_{max} = 208 - (0.7 * age) \tag{7.1}$$

The resting heart rate R_{HR} have not been measured during the experiment session. Hence, we utilized the generalized values for R_{HR} based on age groups. Since our participant engage in sports activities sami-regularly, we opted for the *average* generalized R_{HR} values.

[1] The color represents the condition the participant belongs to.

The heart rate reserve (HR_R) represents the difference between participant's heart rate at rest and heart rate at maximum effort, and has been calculated as follows:

$$HR_R = THR_{max} - R_{HR} \tag{7.2}$$

The Target minimum heart rate (THR_{min}) has been calculated for each participant using the following formula:

$$THR_{min} = HR_R * 0.5 + R_{HR} \tag{7.3}$$

Next, the Target moderate heart rate (THR_{mod}) has been calculated as follows:

$$THR_{mod} = HR_R * 0.7 + R_{HR} \tag{7.4}$$

Lastly, the Intense target heart rate (THR_{int}), to be reached during extreme-intensity anaerobic exercise, is calculated as follows:

$$THR_{int} = HR_R * 0.85 + R_{HR} \tag{7.5}$$

If the participant's heart rate falls into the middle of the (T_{HR}) range, that means the participant is exercising at moderate intensity (roughly 50 to 70% of THR_{max}). In case it verges toward the upper limit, the participant is exercising at high intensity (70 to 85% of THR_{max}). Figure 7.8 presents the calculated target zones for the participants in both conditions.

Condition	Exepriment					Control				
ID	1	2	3	4	5	6	7	8	9	10
RHR	72	72	72	72	75	72	72	72	74	72
HR Reserve	117.8	118.5	117.1	115.7	116.2	117.8	115	117.8	115.1	117.1
THRmin	130.9	131.25	130.55	129.85	133.1	130.9	129.5	130.9	131.55	130.55
THRmod	154.46	154.95	153.97	152.99	156.34	154.46	152.5	154.46	154.57	153.97
THRint	172.13	172.725	171.535	170.345	173.77	172.13	169.75	172.13	171.835	171.535
THRmax	189.8	190.5	189.1	187.7	191.2	189.8	187	189.8	189.1	189.1
Max HR	173	170	174	186	168	159	144	155	167	169

FIGURE 7.8: Computed target zones for participants in each condition.

It can be observed that the maximum heart rate of the participants in the experiment group obtained during the warm up fall in the middle and lower range of high intensity exercise. Only one participant's (ID = 4) heart rate was close to the maximum target heart rate (THR_{max}). On the other hand, the maximum heart rate of the participants in the control group fall in lower range of high intensity and upper range of moderate intensity exercise with one participant (ID = 7) in the middle range of moderate intensity exercise zone. Figure 7.9 depicts the distribution of maximum heart rates participants reached during warm up session in both condition per exercise intensity zones.

Figure 7.9 depicts three distinct zones (*Low, Moderate, and High* intensity zone) that were computed based on participants' age, resting heart rate, and heart rate reserve. Each zone is represented with different color and the circles, grouped by the condition participants belonged to, show the maximum heart rate reached during the warm up session. The figure gives a clearer overview of the intensity of the warm up performed in both conditions. It can be observed that the participants in the experiment group reached higher levels of heart rates compared to the participants in the control group. This can mainly be attributed to the warm up duration differences between the conditions. Participants in the experiment condition were engaged in the exergame which shifted their focus from the exertion resulting in longer warm up duration.

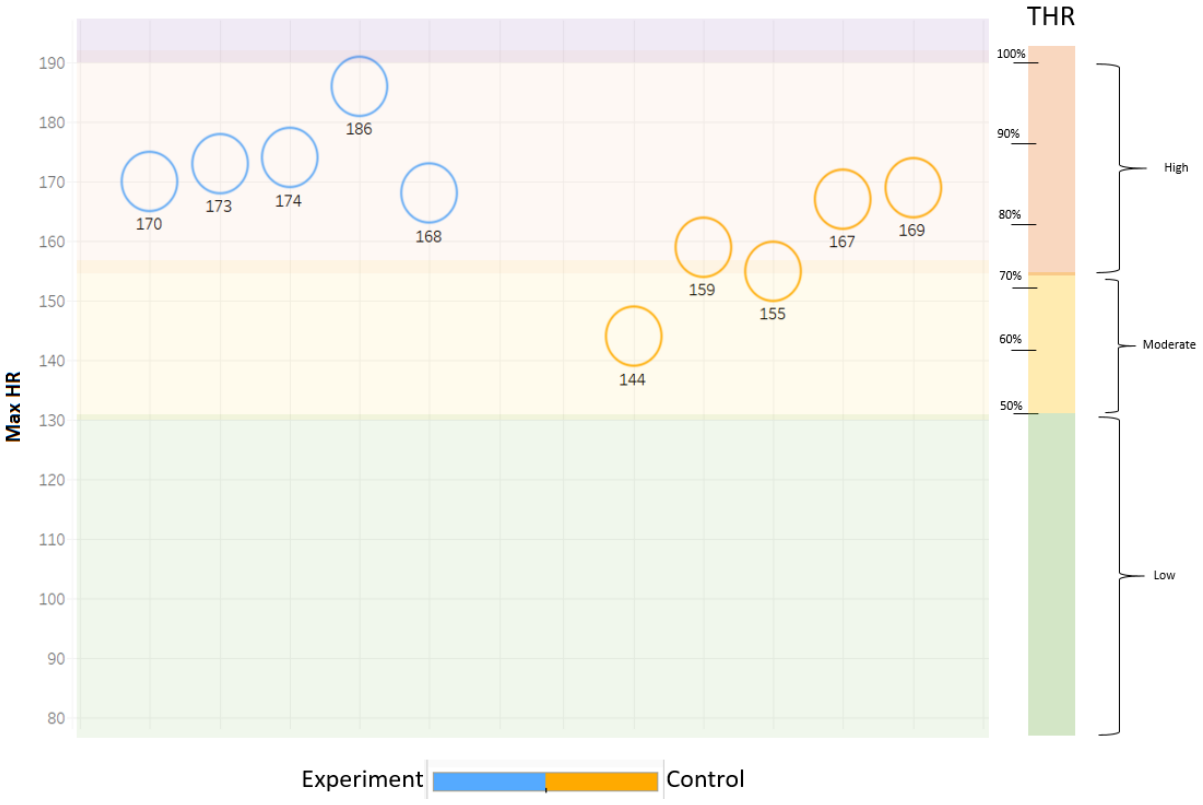

FIGURE 7.9: Target heart rate with exercise intensity for each participant

Overall, we conclude that participants in both conditions reached an elevated heart rate sufficient to continue with the more strenuous physical activity. The results, however, suggest that the duration of the warm up session for the participants in the experiment group could be shortened in order to keep the heart rates at moderate levels as recommended by fitness experts. That is, we noticed that some of the participants in the experiment group spent notable amount of time in the intense heart rate zone and were close to reach their maximum heart rate before finishing with the warm up procedure.

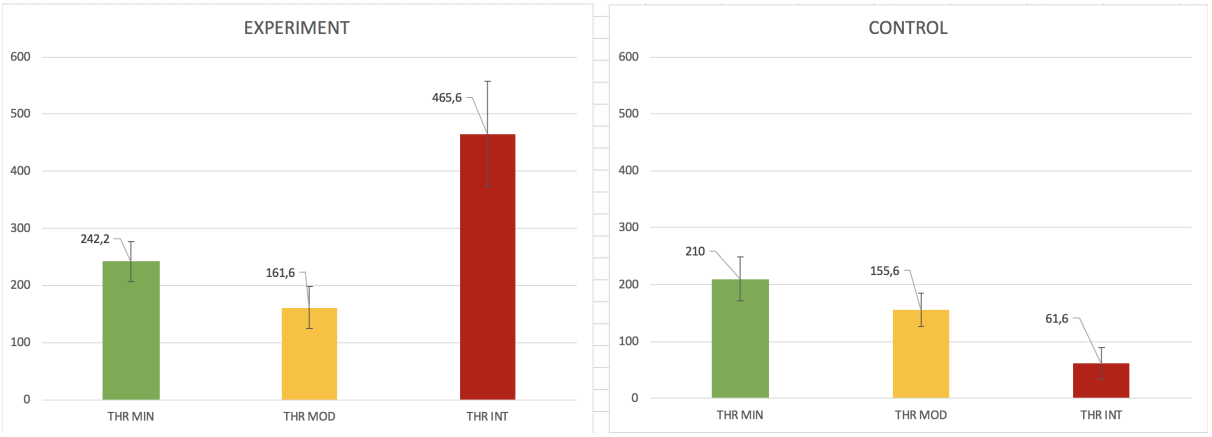

FIGURE 7.10: Average time spent in zones based on participants heart rate.

It can be observed from Figure 7.10 that the participants in the experiment condition ($M_{min} = 242.2, SD_{min} = 77.7, M_{mod} = 161.6, SD_{mod} = 83.001$) spent almost identical amount of time reaching the moderate and intense heart rate as the participants in the control condition ($M_{min} = 210, SD_{min} = 86.16, M_{mod} = 155.6, SD_{mod} = 64.68$). However, the amount of time spent in the high intensity heart rate zone is considerably longer for the participants in the experiment condition ($M_{int} = 465.6, SD_{int} = 204.1$) compared to the time spent by the participant in the control condition ($M_{int} = 61.6, SD_{int} = 62.48$). This can be attributed to two factors. Firstly, the average duration of the warm up session in the experiment condition was longer compared to the average duration of the warm up session in the control condition. Thus, participants spent more time in the intense heart rate zone and were closer reaching their maximum heart rate. Secondly, two participants in the control condition stopped with the warm up session before reaching the intense heart rate zone. This impacted and notably reduced the average time spent in the high intensity heart rate zone. Hence, we believe that having an option to choose the warm up duration is a good decision in order to keep athletes' heart rates in the advised heart rate zones. In summary, the results of the heart rate analysis of the participants suggest that exergames can be used to prolong the duration of the warm up session and can motivate athletes to reach higher exertion levels.

7.2.4 Physical Activity Enjoyment Scale

Given the benefits of physical activity and WU procedures, we needed to understand better how participants perceived the physical activity they have engaged in. For this purpose we utilized the Physical Activity Enjoyment Scale (PACES). The test consists of 18 questions in a 1 to 7 Likert scale that was originally designed to measure positive affect associated with involvement in physical activities in college students [103].

The high scores obtained on the positive items and low scores on the negative items indicate a high enjoyment of the physical activity. Whereas, the total enjoyment score is obtained by reversing negative item scores and summing them to positive item scores. We coded participants' responses, where higher scores indicated greater enjoyment, with scores ranging from 18 to 126. The participants in both conditions completed the PACES after finishing with the WU session. Figure 7.11 presents the average results for each question per condition. It shows that the participants in the experiment condition rated consistently higher all the questions with respect to the scores of the participants in the control condition. Two questions received notably much higher score by the participants in the experiment condition:

- Q4: "*I find it pleasurable.*"
- Q5 "*I am very absorbed in this activity.*"

This suggests that the participants found the exergame very enjoyable to interact with and, most importantly, the exergame succeeded in immersing the participants sufficiently to shift their focus from the exertion of the exercise making it pleasing and entertaining. All the questions can be found in Appendix XXX.

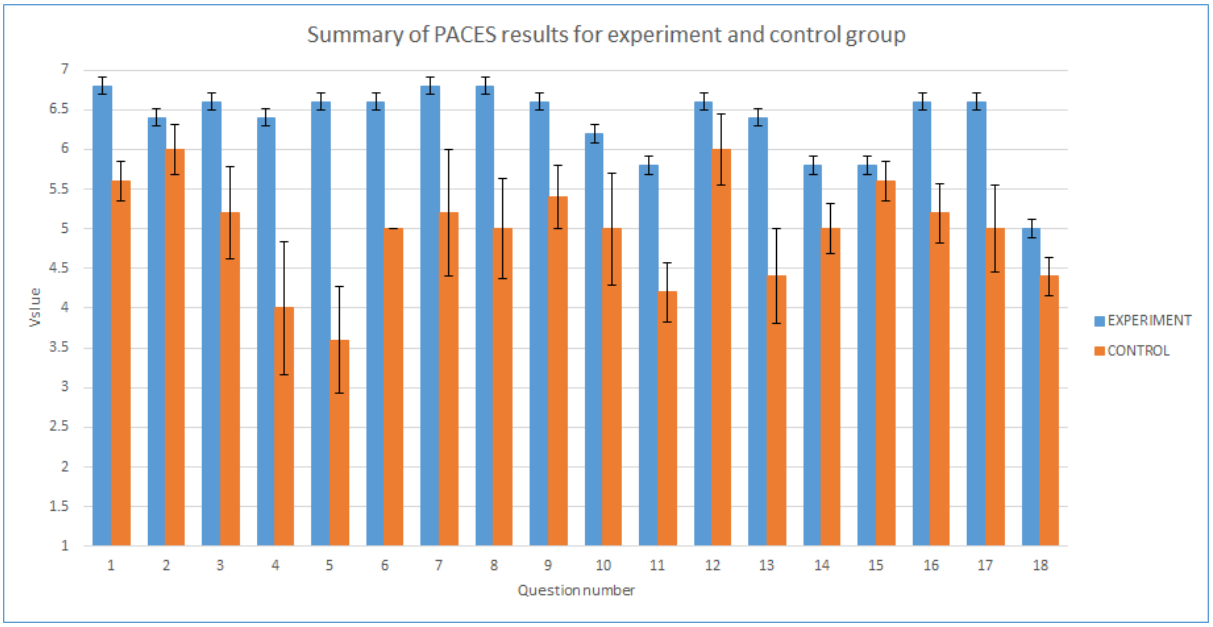

FIGURE 7.11: Summary of PACES results for the control and experiment group.

Figure 7.12 depicts the average scores for all questions per condition. It can be observed that the average score for the control condition is $M = 89.8$ ($SD = 11.97, x_{max} = 104, x_{min} = 71$), which is already high, but for the experiment condition is even higher $M = 114.4$ ($SD = 5.98, x_{max} = 125, x_{min} = 111$).

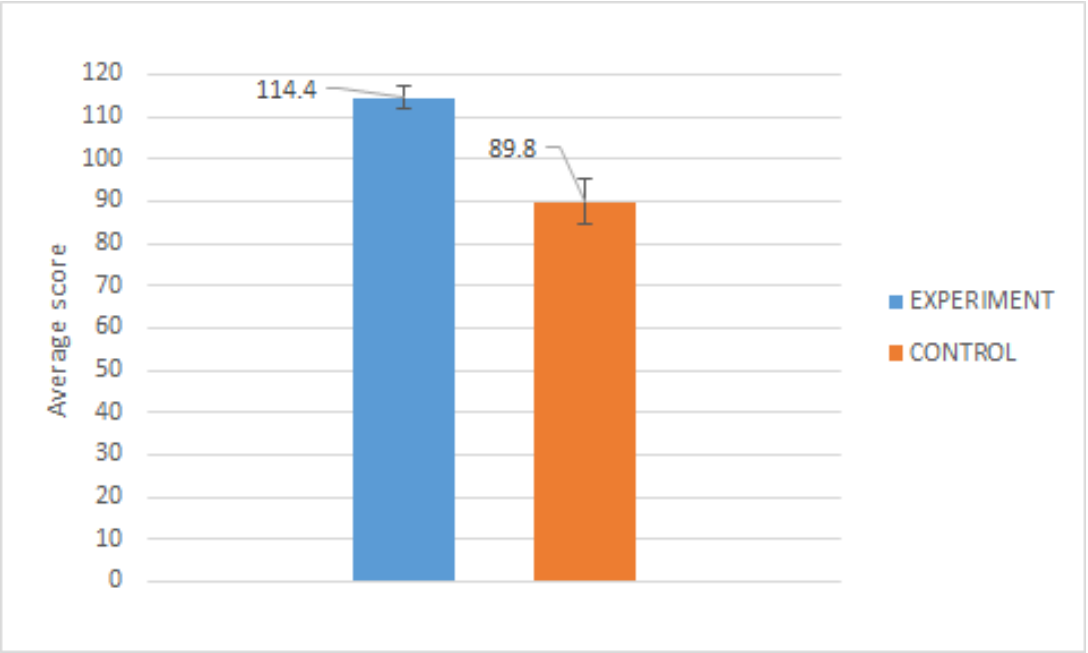

FIGURE 7.12: Average PACES scores for control and experiment condition.

Lastly, we compared the means of the experiment ($M = 114.40, SD = 5.98$) and control ($M = 89.80, SD = 11,97$) group with a??? paired t-test ($\alpha = 0.05$) and found a significant difference; t(8) = 4.1114, p = .0034. Whereas Cohen's d was 2.5948. Therefore, based on the fact that there was a statistically significant difference between the two conditions, we concluded that warming up by using our exergame solution positively affects the physical activity enjoyment.

7.2.5 BORG Rating of Perceived Exertion

The BORG rating of Perceived Exertion (RPE) reflects how difficult the performed warm up exercise feels to the participants, combining all sensations and feelings of physical stress, effort, and fatigue. All the participants received standardized instructions and were encouraged to focus upon their overall (whole body) perceptions of exertion. The participants in both conditions reported their perceived level of exertion after completing the warm up procedure. Figure 7.13 depicts the average RPE results for each condition. The average RPE score for participants in the experiment condition was $M_{exp} = 13.8$ while the score for the participants in the control condition was $M_{con} = 12.6$. It can be inferred that the participants in the experiment condition reached higher levels of exertion while playing the exergame. For the statistical inference tests of perceived exertion after the warm up sessions the t-tests with the effect size (Cohen's d) has been used. The results of the analysis showed that a significant difference does not exist between means of the RPE ($\alpha = 0.05$) of the experiment group (M = 13.8 , SD = 1.10, SEM = 0.49) and control group (M = 12.6, SD= 1.67 , SEM = 0.75); t(8) =1.34164, p = .108274. Whereas Cohen's d was .775.

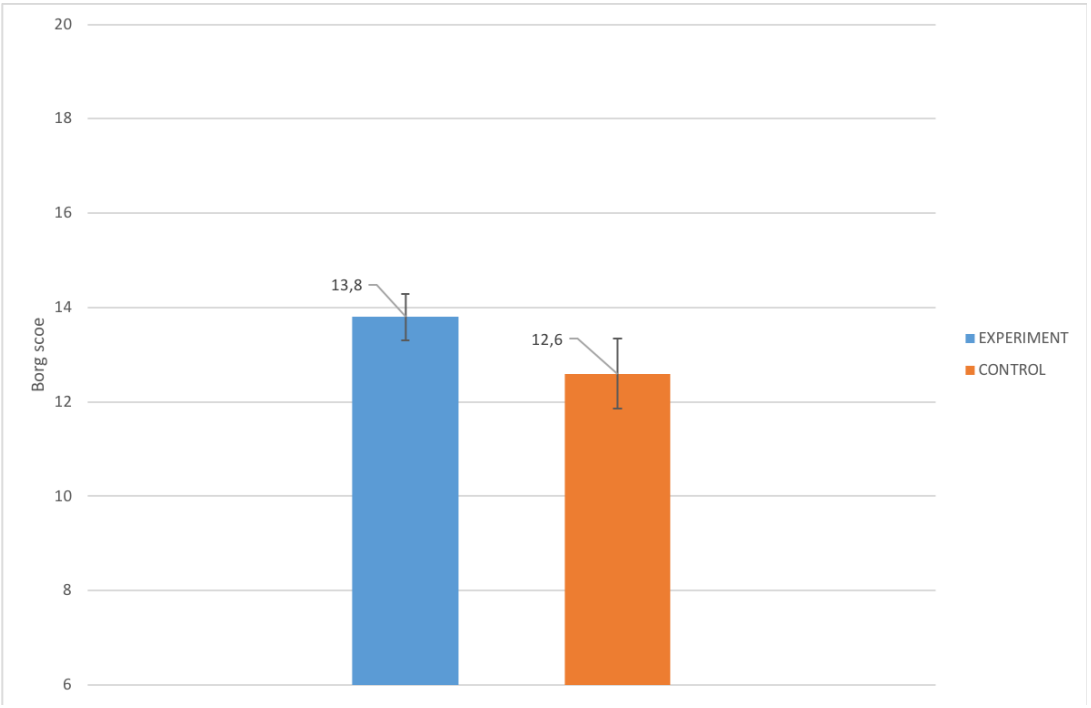

FIGURE 7.13: Summary of BORG results for control and experiment group.

These results suggest that performing WU procedure while playing our exergame does not have an effect on perceived exertion level. Specifically, our results imply that when participants interacted with the exergame, their perceived level of exertion was higher but not significantly different to the one experienced when performed a standard WU procedure.

7.2.6 Self-Assessment Manikin

All the participants reported their momentary feelings of pleasure, arousal, and dominance using a validated 9-point pictorial rating scale immediately after completing the WU session using the Self-Assessment Manikin Scale (SAM) [102]. The SAM scale is frequently used to measure emotion in research on gaming [107] and it is depicted in Figure 7.14. The scores in this scale go from 1 to 9 and are classified as being negative (from 1 to 4), neutral (5), or positive (from 6 to 9). The characters presented in the first row in Figure 7.14 range from sadness and frown to a smile, representing the *valence* dimension. The second row depicts a figure showing a calm, neutral, and passionless face to an anxious and excited face. It represents the *arousal* dimension. The third row represents the *dominance* dimension and the figures range from a very small, insignificant figure to a ubiquitous and pervasive figure. SAM average results calculated for each condition are presented in Figure 7.15. The obtained results indicate slightly elevated scores across the valence and dominance dimensions in the experiment group.

On the other hand, the average arousal score in the control group was higher compared to the average score of the experiment group.

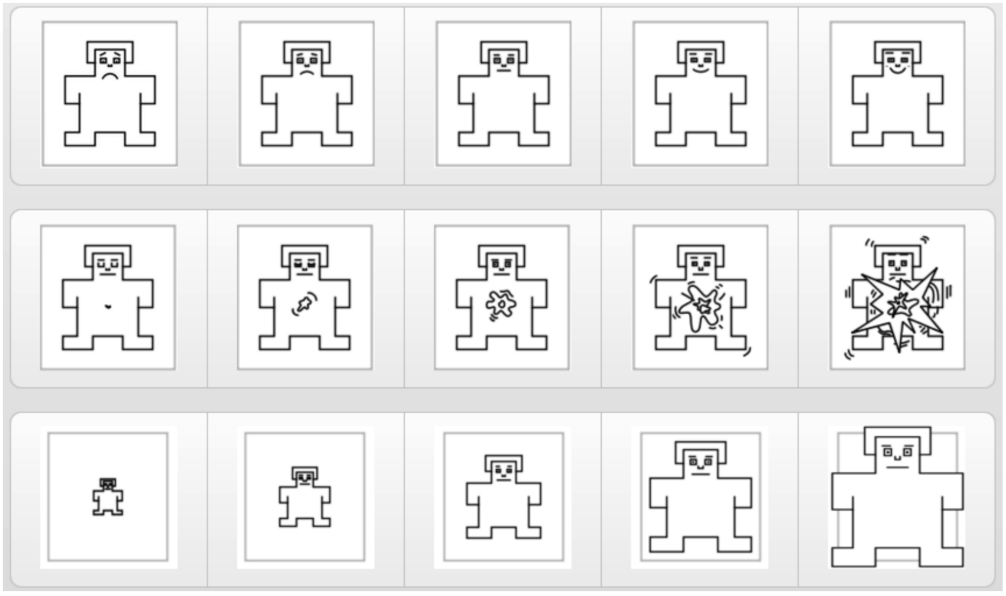

FIGURE 7.14: The Self-Assessment Manikin (SAM).

For the statistical inference test of the subjective ratings of present emotions after the WU sessions we performed a t-test and also reported the effect size (Cohen's d). After the performed analysis, we concluded that a significant difference exists only between means of the *valence* dimension at $p<0.05$ of the experiment group ($M = 7.20, SD = 0.447, SEM = 0.2$) and the control group ($M = 6.00, SD = 1.00, SEM = 0.45$); $t(8) = 2.4495, p = .040, d = 1.73$. The performed analysis did not show any significant difference between scores in the *arousal* and *dominance* dimensions.

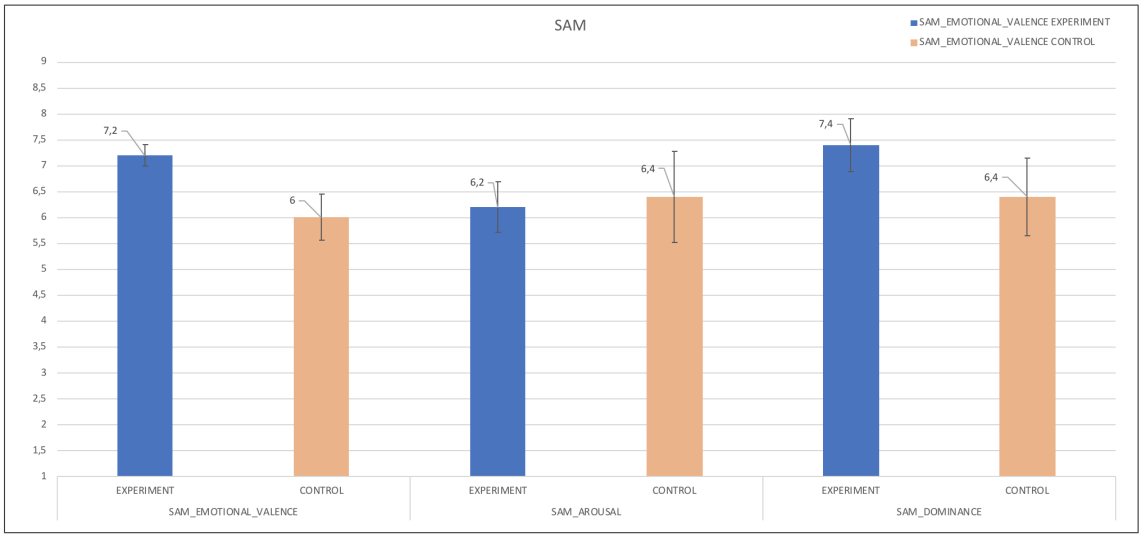

FIGURE 7.15: Summary of SAM results for control and experiment group.

These results suggest that our exergame does have an effect on participants' feeling of pleasure. Specifically, our results suggest that when our exergame solution is used for warming up before physically more demanding exercise, the pleasure and enjoyment of the activity is higher compared to the one experienced during regular warm up routines.

7.2.7 System Usability Scale

The System Usability Scale (SUS) is a reliable tool for measuring the usability of a system under test. It consists of a 10 item questionnaire with five response options for respondents from *Strongly agree* to *Strongly disagree*. The sum of the 10 items in the questionnaire leads to a general measure of perceived usability of the system. The participants' scores for each question are converted, added together, and then multiplied by 2.5 to convert the original scores of 0-40 to 0-100. Even though the calculated scores are between 0 and 100, these are not percentages and should be considered only in terms of their percentile ranking. A SUS score above 68 would be considered above average and anything under 68 as below average. Only the participants in the experiment condition took the SUS questionnaire since only these participants interacted with the exergame system. The summary of the SUS scores for each participant is presented in Figure 7.16. It can be observed that the participants who interacted with the exergame gave the exergame relatively high scores. The average SUS score for our exergame was $M = 76.7$ ($SD = 8.16, x_{max} = 90, x_{min} = 72.5$). This implies that our system usability received *excelent* adjective rating and a B on a grade scale [108].

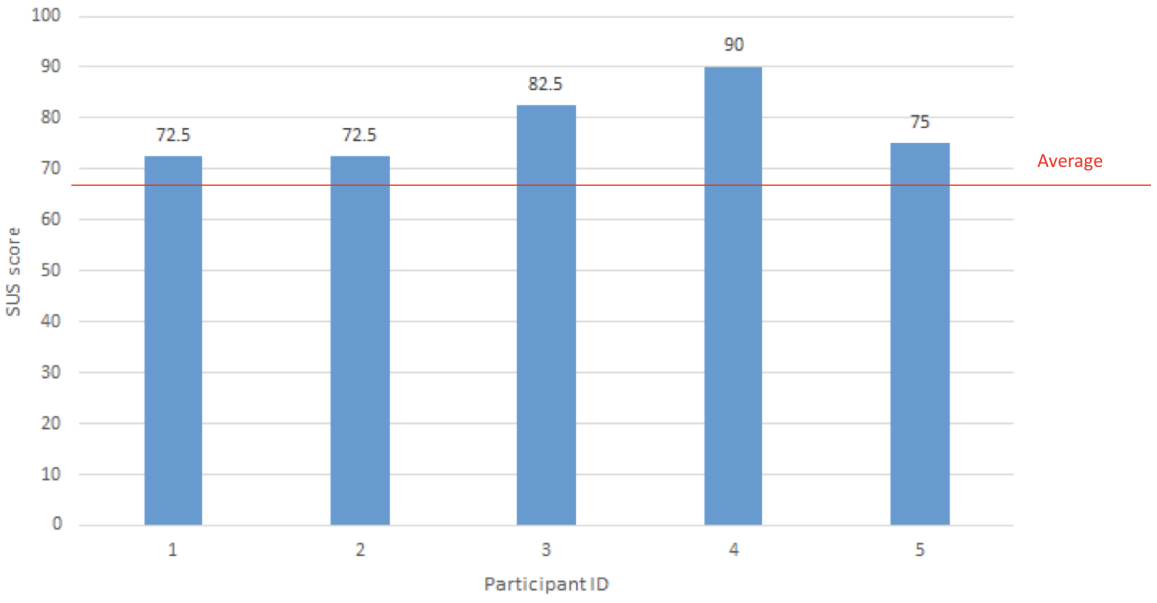

FIGURE 7.16: Summary of SUS results per participant.

The SUS average scores per question are depicted in Figure 7.17. It can be observed that the participants found that the various functions in the exergame have been well integrated and that they felt very confident using the exergame. Furthermore, all the participants agreed that people would learn to use the exergame very quickly. Also, they did not find the exergame unnecessarily complex or having any unconsistencies during gameplay.

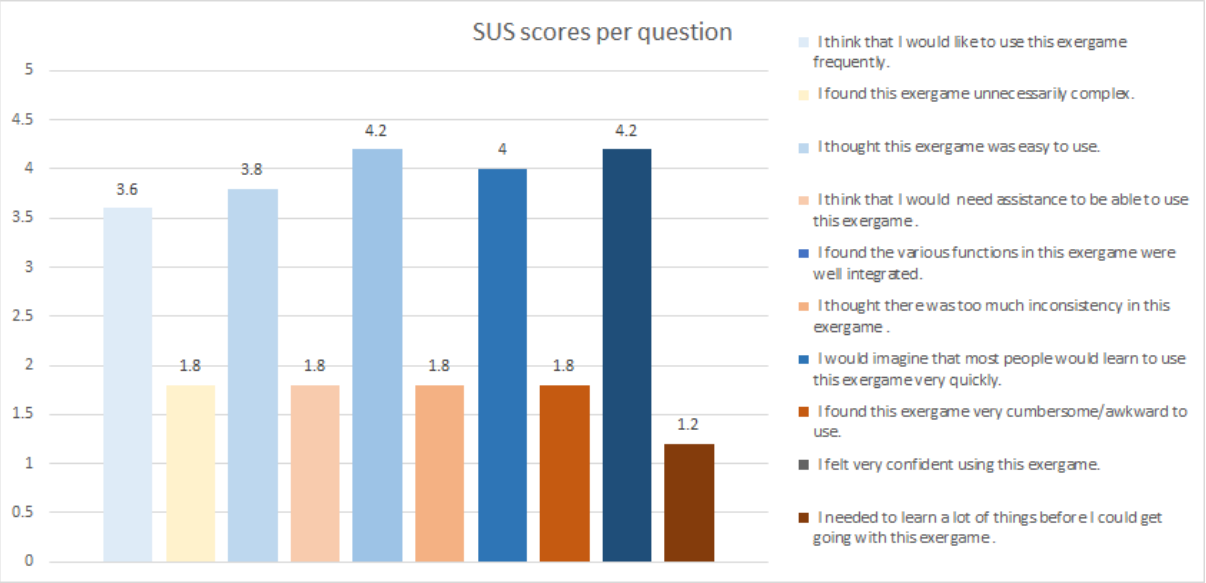

FIGURE 7.17: Summary of average SUS results for each question.

They also thought that it was not difficult or awkward to use, and that getting familiar with the game was pretty straightforward and fast. When asked if they would like to continue playing the game frequently, 3 participants agreed with this statement, 1 neither agreed nor disagreed, and 1 disagreed.

7.2.8 Play Experience Scale

The Play Experience Scale (PES) is a valid and reliable 16 items questionnaire with five response options for respondents from *Strongly agree* to *Strongly disagree* [104]. It has been utilized in order to assess play experience, the usability, and the level of enjoyment induced by our exergame. The PES scale collects responses across four experiential dimensions:

- *Freedom* captures a state in which an individual is free in a play context to act without any constraints.
- *No Extrinsic* addresses a state in which the individual does not feel there are real -world consequences to her play.
- *Play Direct* addresses the play itself.

- *Autotelic/Focus.* When experience is autotelic, an individual engages in it solely for its own rewards. That is, the experience is intrinsically motivating. Focus, on the other hand, targets the states of immersion and concentration during play. It is related to engagement and flow, and the items in this category reflect on the loss of concern and focused concentration.

Figure 7.18 summarizes the PES results per question for each dimension discussed [2].

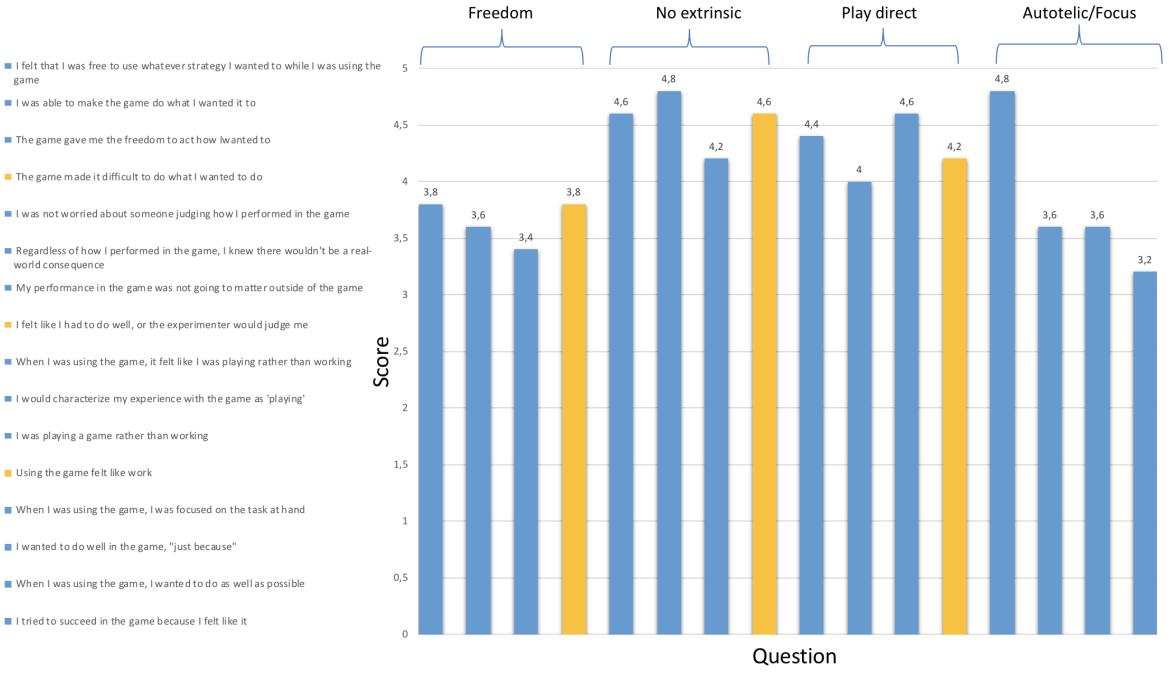

FIGURE 7.18: Summary of average PES scores per question.

In general, the participants enjoyed the play experience induced by our exergame, which can be concluded from high average scores for the questions in each dimension. The lowest scores were obtained in questions that belong to *Freedom* and *Autotelic/Focus* dimensions. The highest scores were obtained in questions that belong to *No Extrinsic* and *Play Direct* dimensions. The scores from *No Extrinsic* dimension suggest that the play induced by our exergame solution was not contingent by external rewards or consequences. That is, the participants felt that there were no consequences to their play, either via evaluative judgement by the researcher or through real-world implications for the WU performance. High average scores in the *Play Direct* dimension imply that the participants believed they engaged in play as defined by [104] and not work. This information is valuable since it suggests that the warm up induced by our exergame has not been received as a tiresome activity as reported for the standard warm up procedures. On the other hand, relatively lower average scores in the *Freedom* dimension imply that the players felt they have not had total control over the play.

[2] Yellow bars have been reverse-coded.

When an individual is free in a play context, he or she is not constraind by any means to perform the actions he or she wishes to perform [104]. The following statement received the lowest score in this dimension:

- "*The game gave me freedom to act as I wanted to.*"

This suggests that certain game elements and constraints prohibited the players to act as they would expected to in similar situation, which in turn negatively impacted the play enjoyment. In the *Autotelic/Focus* dimension, one question received surprisingly high score.

- "*When I was in the game, I was focused on the task at hand.*"

This question reflected the state of intense concentration that is related to engagement and state of flow. High average score implies that our exergame succeeded in immersing the player in the activity at such level, the player's concentration was allocated completely for the play task at hand. In contrast, the remaining 3 questions in the same dimension received low average scores. However, this dimension measured the autotelic experience induced by the exergame. Even though the average scores are not extremely low, we cannot claim that the experience was autotelic for the participants and that they engaged in it solely for its own regard. That is, the experience was not fully intrinsically motivating for the participants. The average PES scores for each participant are presented in Figure 7.19.

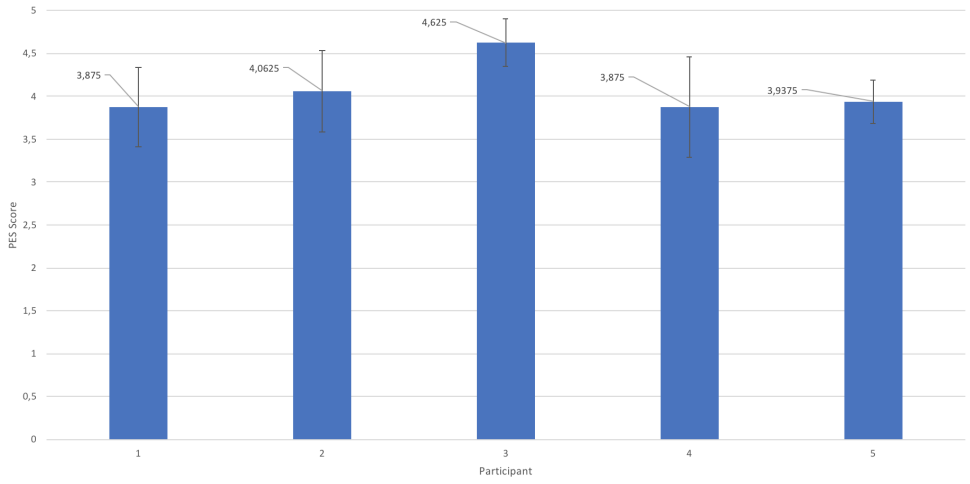

FIGURE 7.19: Summary of average PES score per participant.

As for the previous figure, we can notice the high overall PES score per participant. This imply that, in general, the participants did enjoy the experience induced by interacting with our exergame solution. Most importantly, by creating an enjoyable experience, the exergame successfully shifted participants' focus from the discomfort and exertion of the exercise towards the enjoyment of the experience.

7.2.9 Bartle's Player Types

In order to determine participants' personality types according to their preferred actions within the game, each participant that interacted with the exergame completed an online survey that assessed the degree to which they can be motivated by either intrinsic or extrinsic motivational factors [86]. We chose to utilize this framework and the survey since it is more effective than directly asking users about design elements. Our primary goal was to understand more about user psychology in a gamified context rather than just determining game elements the user enjoys the most. The survey was completed after the WU session and consisted of 24 items which assessed the person's *Hexad user type*, derived from the three types of intrinsic motivation from SDT, namely relatedness, competence, and autonomy. Figure 7.20 depicts the obtained results.

FIGURE 7.20: The Hexad user types of the participants in the experiment condition.

It is necessary to point out that even though users are likely to display a principal tendency or user type, in most cases they will also be motivated by all the other types to some degree. Based on the results obtained, we found that 2 of our participants can be categorized as *Achiever* player type. This player type is mostly motivated by various challenges that allow them to test their knowledge and apply it in order to solve a problem. Overcoming different challenges will make them feel they have earned their achievement.

They are, furthermore, highly motivated by game quests which give them fixed goal to achieve. Leaderboard and different progress and feedback mechanisms can further motivate this player type to perform better in the game. *Free spirit* user type tendencies have been displayed by 2 participants. This user type is mostly motivated by exploration and multiple branching choices. They enjoy being able to choose their path and destiny, whereas the choice has to be or at least feel meaningful to be the most effective and appreciated. One of them has also been categorized as a *Player type*, which is often highly motivated by game rewards, points, leaderboards, and badges. Lastly, 1 participant displayed *Philantropist* player type tendencies. This player type is mostly motivated by meaning and purpose. That is, they have to feel they are part of something greater than themselves, where they can help other players or contribute to the gaming community.
The analysis of player types suggests that, as pointed out by [40] in their review of peer-reviewed empirical studies on gamification, the effects of the utilized gamification elements are greatly dependent on the context in which they have being implemented and on the users using it. That is, our exergame solution should target specific player types that can be motivated and immersed by the elements used in the exergame. These player types should be *achievers*, *players*, and *free spirits*.

7.2.10 Post study questionnaire

As a last step in our experiment, the participants in both conditions completed a *Post study* questionnaire with five response options from *Strongly agree* to *Strongly disagree* that evaluated the participants' overall satisfaction with the exergame and video, and further discussed specifics the participants enjoyed and disliked the most. Participants completed a questionnaire with questions created specifically for one of the condition. Moreover, the questionnaire for the experiment condition contained 3 additional open ended questions regarding possible improvements of the tested exergame. In the following subsections, the results for each condition will be presented and further discussed.

7.2.10.1 Post study questionnaire for the experiment condition

The following statements have been evaluated with the participants in the experiment condition:

- *Using the exergame is a fun way to warm up.*
- *Using the exergame is an exciting way to warm up.*
- *The exergame is challenging to play.*
- *The exergame is frustrating to play.*

- *The exergame is easy to learn to play.*
- *The exergame is boring to play.*
- *I liked the avatar design.*
- *The in-game (live) scoreboard motivated me to play longer.*
- *The possibility to collect more coins motivated me to move more.*
- *I did not care if hit by an obstacle.*
- *The exercise movements induced by coins and obstacles felt intuitive and came naturally.*
- *I would consider using the exergames in order to warm up before physically more demanding exercise.*

The scores for each statement are presented in Figure 7.21.

ID	1	2	3	4	5	AVG	STDEV
Using the exergame is a fun way to warm up.	4	5	5	5	5	4,80	0,45
Using the exergame is an exciting way to warm up.	4	5	5	4	5	4,60	0,55
The exergame is challenging to play.	4	4	5	2	3	3,60	1,14
The exergame is frustrating to play.	2	2	1	3	2	2,00	0,71
The exergame is easy to learn to play.	5	4	5	5	4	4,60	0,55
The exergame is boring to play.	3	2	1	3	2	2,20	0,84
I liked the avatar design.	4	4	5	3	3	3,80	0,84
The in-game (live) scoreboard motivated me to play longer.	4	5	1	4	4	3,60	1,52
The possibility to collect more coins motivated me to move more.	4	5	5	5	4	4,60	0,55
I did not care if hit by an obstacle.	2	1	4	4	2	2,60	1,34
The exercise movements induced by coins and obstacles felt intuitive and came naturally.	5	4	3	4	4	4,00	0,71
I would consider using the exergames in order to warm up before physically more demanding exercise.	4	4	5	4	4	4,20	0,45

FIGURE 7.21: Post study questionnaire scores for the experiment group.

Based on the scores presented in Figure 7.21, we concluded that the participants found the exergame to be a fun and exciting way to perform a WU procedure. Moreover, they found the exergame easy to learn how to play and interact with. On the other hand, not all the participants found the game challenging. Out of 5 participants 1 did not find the exergame challenging enough for warm up procedure and 1 gave a neutral answer. In general, they found the exergame not boring and not frustrating to engage with, with exception of 3 participants who gave neutral answers. Regarding exergame elements, the participants liked the avatar which has been used as a main character in the game. The possibility to collect more coins during game-play motivated all the participants to move more and play the exergame longer. The in-game scoreboard that displayed the player's position was found motivating to all except 1 participant. This implies that the duration of the warm up session induced by the exergame can be partly attributed to gamification elements also.

Out of all the participants, 2 did not care if hit by an obstacle. The exercise movements that were induced by the coins and obstacles felt intuitive and came naturally to all except 1 participant who gave neutral answer. This result suggest that the participants felt that the exergame provided adequate guidance in executing the warm up procedure. Lastly, all the participants stated they would consider using the exergame for warming up.
Three open-ended questions were asked from the participants in the experiment group apart from the discussed statements. The questions were as follows:

- *Which features did you like the most?*
- *Which features did you dislike the most?*
- *How would you improve the exergame?*

Overall, the participants appreciated the way our exergame has been designed to focus only on the major muscle groups. This was an interesting feedback, since some participants argued they usually perform specific warm up procedures before sports activities which entails specific exercises and movement. This lead us to believe that our exergame solution could be useful and interesting for athletes that engage in sports that require specific movements.

- "*... this is an interesting strategy and i get a feeling to do warm up sessions seriously.*"

Regarding features the participants disliked, the critics were mostly related to the responsiveness of the exergame. This can be attributed to the jitter that occurred during some gameplays. The game would *freeze* for a second, which negatively impacted the overall experience. We believe this was a hardware issue and will be resolved in the future release of the exergame. When inquired about possible exergame improvements and recommendations, the participants gave valuable suggestions. First, they would enjoy certain indicators of the correctness of the performed movements. This way, they believe, the badly executed movements could be corrected during the gameplay. Next, introducing new and more diversified movements have been brought up by the participant also. The participants stated that adding additional and more difficult movements one is require to perform as the game progresses would make the exergame more engaging and challenging. Lastly, participants would prefer an exergame with adjustable duration. This option has already been implemented but disabled during the experiment. We believe this feature would positively impact the *freedom* dimension of the exergame as the participants would be able to constraint the duration as per their current physical abilities and competence.

- "*... make fixed amounts of time or levels where one can compete under the exact same parameters.*"

7.2.10.2 Post study questionnaire for the control condition

The participants in the control group had also taken the post study survey which was modified in order to assess the elements of a warm up procedure guided through the video. The following statements have been evaluated with the participants in the control gorup:

- *Using the warm up video is a fun way to warm up.*
- *Using the warm up video is an exciting way to warm up.*
- *The video warm up is challenging to play.*
- *The video warm up is frustrating to play.*
- *The video warm up is easy to follow.*
- *The video warm up is boring to play.*
- *I would consider using the warm up video in order to warm up before physically more demanding exercise.*

The scores for each statement are presented in Figure 7.22.

ID	1	2	3	4	5	AVG	STDEV
Using the warm up video is a fun way to warm up.	4	3	3	4	4	3,6	0,55
Using the warm up video is an exciting way to warm up.	4	4	3	4	3	3,6	0,55
The video warm up is challenging to play.	4	4	3	3	3	3,4	0,55
The video warm up is frustrating to play.	2	3	4	2	2	2,6	0,89
The video warm up is easy to follow.	4	2	1	4	4	3,0	1,41
The video warm up is boring to play.	2	3	3	2	3	2,6	0,55
I would consider using the warm up video in order to warm up before physically more demanding exercise.	5	5	3	4	4	4,2	0,84

FIGURE 7.22: Post study questionnaire scores for the control group.

From Figure 7.22 we observe that 3 participants found that following the video instructions was a fun and exciting way to warm up, while 2 participants gave neutral answers. Only 2 participants found the video a challenging way to warm up, whereas 3 participants gave neutral answers. Contrarily, as already pointed out, all the participants in the experiment group found the game challenging. In general, the participants did not find the video to be a boring and frustrating way to warm up. Only 1 participant reported being frustrated by the video instructions. It's interesting to point out that 2 participants found the video instructions difficult to follow. Lastly, when asked about using the video on the regular basis, the participants would consider using it for warming up before physical activities. Figure 7.23 depicts the compared average scores with standard errors for the some of the statements discussed.

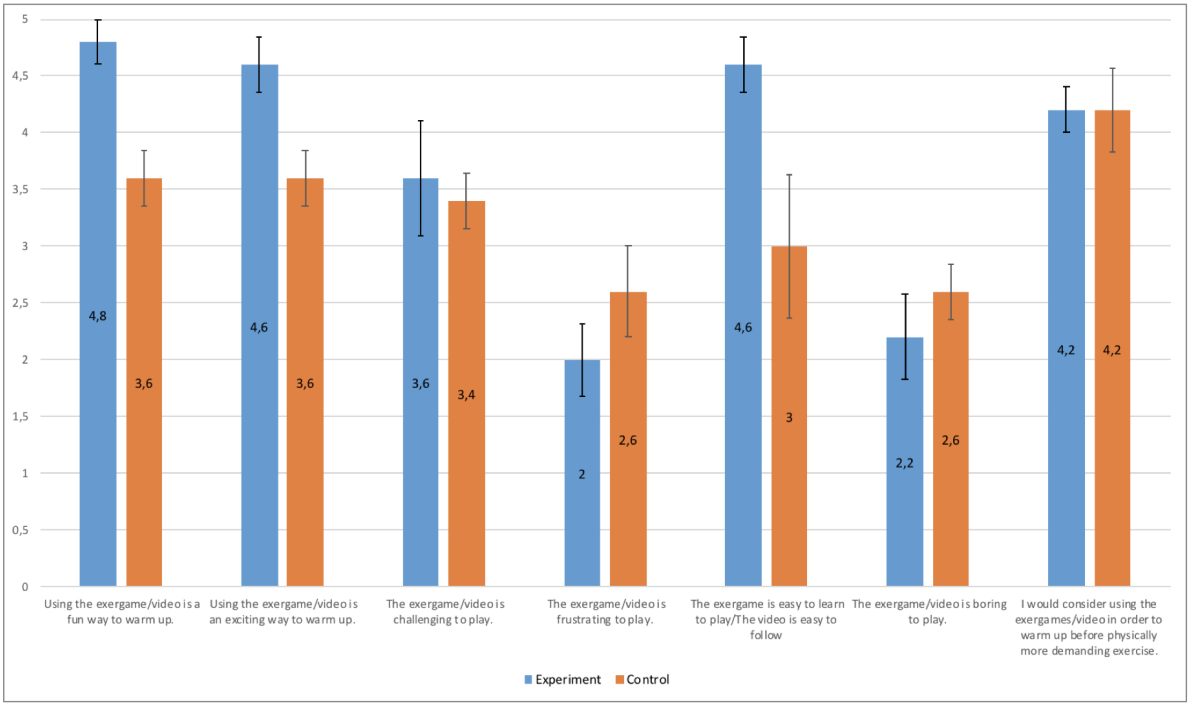

FIGURE 7.23: Average scores of the post study questionnaire for each condition.

We observe that the exergame was perceived more enjoyable and fun way for warming up compared to the warm up with the video instructions. Moreover, the exergame is found less boring and frustrating to play. This only confirms the results obtained in the PES survey. Lastly, participants would gladly use both warm up approaches. However, the standard deviation for the experiment condition is much less compared to the control condition.

7.3 Discussion

The central aim of this study was to investigate if our exergame can be used as a guiding tool for warm up exercises before physically strenuous activities. To the best of our knowledge, no study has investigated the usage of exergames in this context before. As mentioned previously, exergames are usually designed to engage users in a physical activity [109, 51] and are an attractive alternative to physical therapy [110]. Nevertheless, using exergames for guiding users who never or rarely warm up before sports activities has never been discussed in scientific research literature.

In our experiment, we opted for a between-subject design with two groups of subjects. One group interacted with our exergame solution, while the other group followed a video of a professional who guided the participants through the warm up session. The hypothesis that player's ROM is increased for the measured joints after performing the warm up session by interacting with our exergame solution was supported.

We observed that the average values after the warm up session for all measured joints are higher in each experiment condition. This supports previous exergame research results on appropriateness of exergames as an intervention to improve physical functions [111]. The results of our experiment also indicate that performing warm up exercises using our exergame immediately affects the duration of the warm up procedure which supports our second hypothesis. The duration of the warm up session has been measured from the start of the exergame or video instruction, until the participant reported feeling warmed up enough for a hypothetical physical activity. Our analysis showed significant difference in the warm up durations between the two conditions which suggests that warm up duration increases noteably when performed by interacting with our exergame solution. We also observed significant increase in the duration of the warm up session compared to the reported average duration of warm up given in a self-reported pre-study survey. In our questionnaires we also inquired about most common reasons individuals avoid performing warm up exercises. The most common reasons reported by the respondents were time constraint and the monotonous and tiresome nature of the warm up procedure. These results are consistent with the findings of previous research on common reasons why individuals avoid warm up exercises [25]. The results, further, imply that the enjoyment of the physical activity can be improved by playing our exergame. For this purpose, the Physical Activity Enjoyment Scale has been utilized. The obtained results suggest that our exergame positively affects physical activity enjoyment. It's interesting to point out how the results for the control condition were also found to be above average. This implies that participants in the control condition enjoyed the physical activity as well. Nevertheless, there was a significant difference found between the two conditions suggesting that warming up using our exergame positively affects the physical activity enjoyment which supports our third hypothesis. The BORG rating of Perceived Exertion (RPE) has been used in order to determine how difficult the performed warm up exercise felt to the participants. The results showed that there were no significant difference in the perceived exertion between the conditions. Due to the immersive nature of our solution, the expectations were that the reported average exertion level in the experiment condition will be less compared to the one in the control condition. We believe the duration of the warm up session influenced these results the most. It would be interesting to compare the RPE results in an experiment in which the duration of the warm up session is the same between the conditions. Participants in both condition reported their momentary feelings of pleasure, arousal, and dominance using Self-Assessment Manikin Scale scale immediately after performing the warm up procedure. We believe that the assessment of psychological and emotional dimensions, such as enjoyment, arousal, and dominance, together with the assessed level of the enjoyment of the physical activity, could deepen our knowledge of the causes of avoiding warm up exercises. Understanding enjoyment motives and the relationship between enjoyment and other psychological variables can help researchers and practitioners design more effective intervention strategies which could increase the percentage of individuals who warm up regularly before every sports activity. Our analysis showed significant difference in the pleasure dimension between mean scores of the experiment and control condition.

This means that the enjoyment associated with the exergame experience was significantly higher compared to the emotions induced by the video instruction. The results, on the other hand, did not show any significant difference between scores in the arousal and dominance dimension. We believe our research design might not have been suited well enough to cater for dominance and arousal as a player emotions.
Our findings that the Immotion exergame is feasible for guiding amateur sportsmen in performing warm up procedures have several caveats. First, it involved a very small, self-selected sample of students, out of which only 5 interacted with the exergame. This number is small and contains very specific demographics to draw more than tentative conclusions. Even though the results are promising, further research is needed and quantitative results need to be confirmed in future work. Next, we excluded professional sportsmen whose preparation activities include specific exercises currently not supported by the exergame, and only included participants who rarely perform warm up exercises before sports activities. This was the reason why our exergame focused on more general movements that are intuitive and easy enough to be executed without any prior knowledge. Further research is required to investigate how would professionals enjoy the warm up exercise induced by our exergame. Lastly, the study consisted of a single session only. Hence, the longitudinal effects of exergame usage cannot be foreseen. After recurrent interaction with our exergame before sports activities, we believe the user would get familiar to the game environment and required movements. This would, in turn, as with any video game, reduce the motivation to engage with the exergame as well the enjoyment while playing it. This could be avoided by modifying the environment on regular basis. Other approach would be to introduce multiple game levels which would require movements with increasing degrees of difficulty.

While the small sample size, highly selected participants, and short duration of the study represent important limitations of this study, the findings that exergames can guide participants in performing a general warm up procedure, increases the warm up duration, and positively impacts the enjoyment of the physical activity suggest a promising novel, relatively low-cost option for warming up before physically more strenuous activities that deserves further consideration and additional research.

Chapter 8

Conclusion

In this paper we presented a development and evaluation process of an exergame for warm up guidance and motivation that is specifically targeted towards amateur athletes who rarely or never warm up before physically strenuous exercises and sports activities. We used Kinect sensor in order to track and capture players' movements and dispayed the exergame on the wall using a projector. By placing various game obstacle and coins in a specific position, our intention was to indirectly promote exercise through the gameplay of repeatedly performing warm up related movements chosen after related literature review and discussions with fitness experts.

The development of our exergame consisted of three phases that included requirements gathering, prototype development with user evaluation, and final exergame development with further user evaluation. The first phase was an exploratory step in which we justified the development and identified currently available commercial and non-commercial solutions. In our research, we did not find any available solution with primary focus on warm up as a preparatory activity. In the second phase we implemented and evaluated our exergame prototype. The prototype was a scaled down version of our final exergame solution. In order to evaluate our prototype, we created an online survey. The purpose of the survey was to explore general work out and warm up habits of the respondents, as well as their preferences and general acceptance of gamified solutions of warm up exercises. Total number of n = 446 individuals participated in the online survey. With respect to respondents' warm up preferences before a physical activity, n = 251 (56.3%) reported always warming up, whereas n = 195 (43.7%) reported not warming up regularly before physically more demanding exercises. The results regading the reasons for avoiding warm up exercises aligned with the ones presented in [25]. This further justified the need for educational and motivational solutions, which are enjoyable and easy to carry out, with primary focus on the major muscle groups and benefits of warm up, in order to increase the proportion of athletes who engage in warm up routines before every exercise. The prototype exergame and one short warm up session has also been presented in the online survey.

Total of n = 269 (60.31%) respondents reported that would use the prototype exergame for warming up. Out of n = 195 respondents who reported not warming up before sports activities n = 124 (63.58%) stated that they would use the presented solution as a tool for warming up before sports activities. Based on the results obtained from the survey, comments, and suggestions, in the third phase the prototype version of the exergame has been redesigned in order to better suit the needs of its future users. We opted for a modular design, consisting of multiple game segments each containing different obstacles that induced different movement during gameplay. These segments were generated procedurally on random and were easily modifiable. Our primary goal in the last phase was to investigate if our solution can be used to guide athletes through the warm up process efficiently. Despite some limitations, our exergame showed higher results and statistically significant difference in terms of exercise duration, physical activity enjoyment, and perceived exertion level compared to the non-gaming session under the same conditions. The exercise movements that were required to be executed during gameplay felt intuitive and came naturally to the participants. Thus, we concluded that the exergame provided adequate guidance in performing a general warm up procedure. Contrarily to expected results, the evaluation of psychological and emotional dimensions did not show significant differences between two conditions. These results were most likely due to the fact that both conditions involved the usage of immersive technology and a novel approach (game with Kinect sensor and a warm up video) that succeeded in shifting the participants' focus from the discomfort and dullness of the exercise, but the results showed that the exergame condition offered a more immersive and enjoyable experience.

Based on the results obtained in this paper, we conclude that exergames with incorporated immersive technologies can be used as a guiding tool for general warm up procedures and can offer significant benefits as motivational tools to promote engagement in warm up exercises for amateur athletes. Moreover, the exergame design given in this paper was shown to be effective in promoting the desired health outcomes in terms of increased range of motion and expected heart rate recommended by previous studies and medical experts. Lastly, the modular design approach that have been followed in the development of the final version of our exergame solution has been effective for game segment customizations and adjustments. This, further, makes the game easily extensible in case additional movements need to be incorporated for future use cases. Future studies investigating exergames should consider the design approach introduced in this paper, such as the modular design of the game segments, the procedural generation of the exergame environment, and the advantages of immersive technologies.

8.1 Future Work

This paper has tackled several interesting areas worth considering in future works. Firstly, our solution has been designed for general warm up exercises in mind. This means that the movements induced in various game segments could be executed without any prior knowledge of the exercise. However, based on the surveys conducted and the results collected, the respondents who declared themselves as professional athletes found the required movements too general and not applicable for the sports they engage in. Hence, generating versions of the exergame that are designed for certain sports areas, and require previous knowledge of the movements might be worth considering. This way, our solution could be used not only in gyms by amateur athletes, but have more diverse players pool. Secondly, due to hardware constraints, our solution did not take into account the correctness of the movements executed. As pointed out, we opted for general movements that are intuitive and easily executed. Interestingly, we observed that some of the players struggled at the beginning of the gameplay to execute the movements correctly. This resulted in two scenarios. Either the player missed collecting the coin and hit the obstacle, or the coin was collected but the movement was faulty. It would be interesting to see how effective our solution would be in not only guiding the players through a warm up procedure, but in the same time, correcting the movements that are not executed properly. Lastly, survey respondents and study participants indicated an interest of having a possibility for a collaboration during gameplay in a form of a group warm up or a competition. Previous studies already showed that introducing competition in a form of scoreboards can be a powerful motivator for certain player types [41, 60]. Having this in mind, our solution also incorporated game elements suitable for more competitive player types and assessed their effects and acceptance. Even though our exergame in it's current design is not well suited for collaborative warm up session that include multiple players at the same time, the existing high score system could be extended in a way the results are shared on social media platforms further enhancing the competitive aspect. Alternatively, the exergame could be extended in a way it allows multiple players to perform a warm up procedure in the same time, either collaborating or competing among each other.

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