

Development of Exergaming Simulator for Gym Training, Exercise Testing and Rehabilitation

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Abstract: “Video games that require physical activity in order to play” is a common definition of exergames. Products, such as Wii Fit and dance pads, are well-known exergame products targeted to home use. Also exergaming products for professional use are gradually becoming more common in gyms, fitness centers, rehabilitation centers, as well as in activity and amusement parks. A lot of research has been carried out on the benefits that the exergaming products can provide for people of different ages, for example. The results have been promising, and the possibilities of exergaming in the fight against obesity and inactivity have been recognized. New exergaming products are coming to markets in increasing speed. However, the field is still very young, and there is space and demand for new innovations. During the last two years, we have been developing a new exergaming simulator for gym training, exercise testing and rehabilitation. As a next generation exergaming device, the simulator combines various gym and rehabilitation equipment (treadmill, exercise bike, etc.) with virtual environments, games, sports applications, immersive gaming view, and advanced motion controllers.

Key words: Exergaming, Athene exergaming, fitness games, games for health, virtual environment.

1. Introduction

The term exergaming (also exergaming, portmanteau from words exercising and gaming) has become widely used. In their literature review, Oh and Yang [1] explored the various terms and definitions that have been introduced to describe exergames. According to Oh and Yang, the most common definition of exergames is “video games that require physical activity in order to play”. In this article, we define exergames as a video game solution which inspires and motivates people to exercising by taking advantage of different technologies. In most cases, the technology that tracks body movements or reactions is used.

The first steps towards exergaming devices were taken in early 1980s when high cycle and virtual racquetball were introduced by Autodesk [2]. In 1986, Bandai released the Family Trainer pack which

includes powerpad (pressure-sensors embedded between two layers of flexible plastic) with games [3]. A year later, Exus released Foot Craz running pad which was compatible with Video Jogger and Video Reflex games (Atari) [4]. In 1987, the first dance pad game called “Dance Aerobics” was released. About a decade later, exergaming took a huge step forward when DDR (dance revolution) was released in 1998 by Konami. In 2000’s [2, 4], e.g., Nintendo Wii Fit, Eye Toy gesture camera and Move motion-sensing game controller for play station were generating huge revenues in the exergaming field. Good reviews on the history of exergaming products have been published, e.g., by Bogost [4] and Johnson [2].

Exergaming products have been mostly targeted to home markets. However, there is only a limited amount of high quality exergaming products developed for gyms, fitness centers and rehabilitation centers at the moment. With the increasing fight against obesity and inactivity this market will probably quickly expand and create new markets for exergaming. Another growing field is exergame

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training spaces, in which all activities and devices are exergames. Examples of such devices are iDANCE dance game in which multiple players can play together and T-wall in which player's task is to deactivate light by quick touch as soon as it appears on the wall.

Exergaming has also become a part of the traditional exercising equipment. Modern gym devices, such as treadmills and exercise bikes are often equipped with a screen and an integrated computer. The user can choose to play games or use virtual and/or video landscapes during the training. These devices with additional integrated applications, such as social media and web browser, may motivate and bring fun for the users. Nevertheless, the lack of immersion due to the small screen and the limitations in the control possibilities of the game (most often, it is only the speed that can be controlled) may restrict their usability and leave space for innovations, in which these features are developed to a new level. There are also some products in which an exercise device is connected to a computer and a screen (e.g., TacX, Spivi Indoor Cycling Training system) or to a mobile application (e.g., Kickr, BitGym).

Several research groups, individual researchers and laboratories have concentrated on the scientific study, development, and/or testing of exergaming products in order to examine possible benefits of the use of the exergame devices. Examples on research groups concentrating on exergaming are such as Exergame Lab in Coastal Carolina University, XRKade Research Lab at University of South Florida, the Canadian Exergaming Research Centre and ExerGame Lab in SUNY Cortland's Kinesiology Department. The research has concentrated, for example, on possible physical and psychological benefits of exergames for different ages (e.g., children, seniors) [5-7] and for different target groups (e.g., inactive children, rehabilitation groups) [8]. Also the use of virtual environments in exercising has been studied [9]. The results indicate generally that

exergames have positive psychological and physical impact to the studied groups. The studies have shown, for example, an increase in the exercise motivation [10], physical activity [8] and energy expenditure while playing exergames [7, 11] and improvement of the balance [6], mood and attention after playing [12]. However, also some studies exist with no clear evidence of the benefits [13], but no harmful effects have been reported. In Section 2, we describe the background for the development project; Section 3 presents the phases in the development; the constructed product prototypes are introduced in Section 4; it is followed by the review in the pilot cases of our exergaming simulator in Section 5; finally, the paper is finished with discussion in Section 6.

2. The Background of the Project in Kajaani University of Applied Sciences

During the last two years, we have been developing in Kajaani University of Applied Sciences a new kind of exergaming simulator for gym training, fitness testing and rehabilitation. In order to bring exergaming to a new level, we have been constructing a simulator which integrates different exercising and rehabilitation devices, immersive virtual environments, games and advanced motion controllers.

Our core team worked previously in the University of Oulu where our focus was to develop driving simulator solutions [14] and carry out psychological research in the fields of simulator sickness [15] and driving skills [16, 17]. During the research and development of driving simulators we learned, for example, how to create high quality virtual environments, how to build and use a multi-screen CAVE environment, and how to control and fine tune different motion platforms. In 2012, we continued our work at Kajaani University of Applied Sciences, where we built on a 6-DOF motion platform a high-end driving simulator with a cockpit of a real car, a real driving wheel, gauges, a gearshift, and pedals.

During the development of the simulator, we started to plan how to apply our knowledge and expertise of simulators to the area of sports, games, well-being, health, and tourism, which are the strengths of the Kajaani University of Applied Sciences in which also game education is internationally well-known.

3. The Phases in the Development Project

The construction of the new exergaming solution started in the beginning of 2013. The project received funding from the Cemis Development Programme (EU funding) and expanded six months later with a parallel Game Testing project supported by the Finnish Funding Agency for Technology and Innovation and 17 project partners. Game companies, such as Supercell and Remedy, and organizations active in tourism, sports, healthcare, education and technology, joined to the project, and provided resources and expertise for the project.

At the present, Athene Exergaming team consists of specialists from different areas. The project organization is divided to Lead, Software and Technology teams which are working closely together. During the project, special attention has been paid to the improvement of communication between the different teams. It is difficult to develop efficiently a new product together if the vocabularies do not match. The team uses an iterative and incremental agile software development framework for managing product development (SCRUM). Each morning, the software team has their standup in which everyone reports on the progress made since the last meeting, goals for the next one and if they have confronted any impediments. The progress is followed in one week periods by weekly sprint reviews in which the team reports its accomplishments to the whole project organization.

An important step in the product development process and QA management was taken when we started to use a new testing tool called the deeper game testing software developed in our previous game

testing services development project. This software enables simultaneous monitoring of the test person, the view of the virtual environment and the physiological signals. It is also possible to add synchronous comments and mark important findings in the time-line of the software. The software shows all data and video records synchronized together.

In the beginning, we did not know exactly which group will be mainly targeted in our project. We designed a three-step roadmap in order to find out the potential customers for the product and to recognize the product's prospects in the exergaming market. The first step was to carefully select the project partners from many different areas that could help us: (1) in finding the existing solutions, potential needs and markets for the exergaming simulators and (2) in providing information about the business potential in the field they represented. The collaboration has been fruitful especially with sports, gaming, technology, and healthcare sectors. The second step consisted of mapping carefully existing products, creating networks, and testing different exergaming solutions, which helped us to get acquainted with the state of art of the exergaming field. Based on all this information and our analyses, we decided to focus, primarily, on developing the exergaming simulator for gyms and secondarily, on exercise testing and rehabilitation. The third step was to build several pilot setups in which the simulators were tested for different purposes with different kinds of test groups.

4. Constructed Prototype Products

Athene software is based on Unity 3D game engine. It includes various virtual environments with a free run option in which the user can explore the area freely, or use several routes of different lengths and difficulty levels. The Finnish forest (Virtual Vuokatti) and the city (Virtual Kajaani) environments, a tropical island and mountain scenery are the first available virtual environments. Our team is currently developing a software tool which semi-automates the

creation of virtual environments that are based on real environments, in order to be able to add new virtual environments efficiently and quickly.

The software includes variety of exercising modes, such as jogging, biking, orienteering and adventure. Gaming plays a major role in all exercising modes. For example, it is possible to challenge a friend in an adventure game or in future, participate in competitions in which several people are participating via Internet. Also in fitness testing, the users may challenge themselves or their friends by competing against avatar characters based on their previous exercise results. The software includes also support for different add-ons, such as heart rate monitor, stride and cadence sensors and Oculus Rift.

At the present, there are three prototypes in the Athene Exergaming product family. The Athene Basic is a light version of Athene Exergaming. It has been designed for limited space requirements. It includes the Athene software, a PC, a television or projector, the Kinect motion sensor and ACD (Athene communication device) and a sensor to the exercise machine or a connection to exercise device's interface. It also includes Athene wall, which provides a safe place for devices and wires, and polishes the product looks. In the Athene Advanced (Fig. 1), three televisions are used to create an immersive exergaming experience. The setup is provided with an Athene triple wall structure.

Athene premium (Fig. 2) provides an ultimate exergaming experience. Three video projectors and the CAVE structure enhance the virtual environment to the next level. There is also a more lightweight CAVE structure which can be easily passed from one place to another.

ACD has a size of a match box. It enables communication between the exercise device and the Athene software and includes also different sensors (for recording of heart rate, cadence, stride and acceleration). It is supported by the most typical wireless protocols, such as ANT+ and Bluetooth 4.0.



Fig. 1 The Athene advanced prototype with KICKR device.



Fig. 2 The prototype of Athene premium with Curve treadmill was introduced in FIBO2014 in Cologne.

ACD is the key for the integration of different exercising devices into Athene Exergaming. The full integration can be made directly by using device's interface, which is usually realized in collaboration with the manufacturer. In this case, information can be read from the device (speed, RPM, etc.) and the recorded data can be sent to the device (angle of actuators, resistance, etc.). The semi-integration means that the data can be read by the device interface, but the data cannot be sent to the device. The third option is to attach a HALL sensor, for example, to the device, and then calibrate the received data from the sensor in order to get the device synchronized with the speed of the virtual environment. Currently, the integration has been made with Woodway Curve and Tunturi Pure Run 10 treadmills, HUR Monark FCM exercise bike, Kickr bike trainer, THERA-Trainer Tigo restorator and a couple of other devices.

5. Pilot Cases in the Use of the Exergaming Simulator Prototypes

During the project, we have carried out several pilot studies in order to: (1) find out how well the constructed exergaming simulator fits for different target groups; (2) recognize the strengths and weaknesses of our prototypes and (3) analyze the business prospects of different target markets.

Athene for orienteering: our first setup of the Athene Exergaming was an orienteering simulator in which a treadmill, Kinect motion controller, high quality virtual environment, CAVE visual system and an in-house programmed orienteering game were integrated. This pilot case was chosen, because the World Orienteering Championships were held in our region providing a unique environment to examine and validate the simulator. During the Championships, the sportsmen and other visitors were able to try the simulator and the orienteering game. The task in the game was to find in three minutes as many checkpoints as possible by in the virtual city of Kajaani which was presented by three projectors on a large screen (Fig. 3). The players were running and could use a real orienteering map of Kajaani as the virtual Kajaani is an exact copy of the real environment in Kajaani. In order to synchronize the dynamic display with the speed of the user, we attached in the treadmill a HALL-sensor, which calculated the speed of the treadmill and transferred the speed information into the game controlling computer. The Kinect motion sensor was used to recognize the user's gestures in controlling the direction into which the player was running. The user could control the direction of each turn by tilting the head or moving the hand.

After each test run, the user was asked to answer a questionnaire, and give feedback by using the Survey iPad application. The data were gathered from 305 professional and national level athletes. Fig. 4 presents a summary of the main results.

Athene Exergaming for gym: the second pilot

examination was designed for fitness centers and gyms. We tested Athene Advanced with three televisions and Athene Premium with CAVE visual system in Health Club Hukka which is one of the largest privately owned indoor exercising facilities in Finland. Athene Exergaming was there in test use for nearly four weeks in May-June 2014. The users were able to select between four different routes (two predefined routes and two options with free run option). We collected data from 56 users by using Survey questionnaire and studied if there was any difference in the opinions between the different age groups. We divided the groups roughly in two categories: subjects with 35 years or less, and subjects over 35 years. The results show, for example, that there was no marked difference in the number of answers to the statement "Virtual environment made exercising more fun" (Fig. 5).

Athene Exergaming for exercise testing: in June 2014, we took Athene Exergaming to Vuokatti Sport Testing Center. In this third pilot examination, three athletes tried the exercise testing application of Athene Exergaming. Our light demo version of Athene Exergaming consisted of ACD card connected to treadmill, PC and a video projector. Each test person was interviewed after the test. Their feedback was positive and several suggestions for development were received for the athletes' training.

The task was to ski with roller skis on a treadmill up to the top of the Vuokatti hill (Fig. 6). The route in our software was a virtual environment of the real route that is used for exercise testing by the sportsmen. Also the angle of the treadmill followed the angle of



Fig. 3 Athene exergaming for orienteering was introduced at WOC2013.

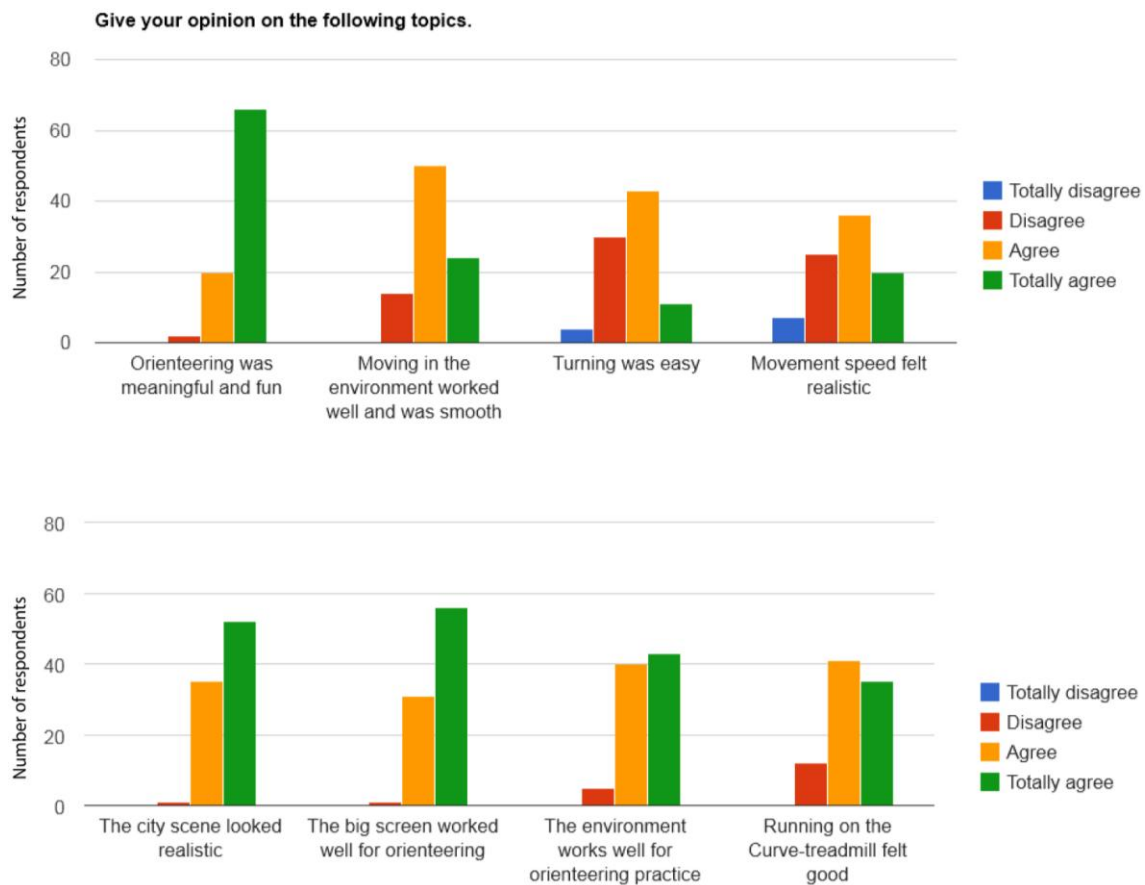


Fig. 4 Distribution of the user opinions when testing Athene Exergaming during the World Orienteering Championships 2013 (data from 305 users).

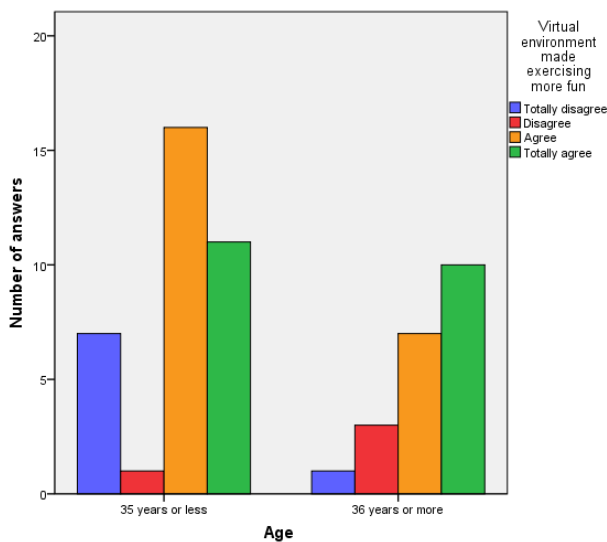


Fig. 5 Distribution of answers to the statement "Virtual environments made exercising more fun" (N = 56).

the real road. We measured the heart rate of one subject on the treadmill, and during the following day he did the same exercise in the real environment (both

exercises were done with a speed of 10.6 km/h). There were no marked differences in the synchronized heart rate curves between the two tests. This similarity indicates quite cogently that the workload in the real environment and in the simulated setup may well be comparable. It will be interesting to have more research on this topic.

Athene Exergaming for the activity park: the fourth pilot examination consisted of testing the exergaming solution in an activity park. Angry Birds Vuokatti is the largest Angry Birds indoor park in the world and we got the possibility to bring Athene advanced prototype there to be tested among a bit different user group than in the earlier tests. For one month, three different games (Tropical Island Adventure, Lost in Kajaani Orienteering and Kajaani Free Run) were available for playing by walking or running on the Curve treadmill to control the speed. Kinect motion control was used



Fig. 6 Athene Exergaming was tested at Vuokatti Sport Testing Center in June 2014.

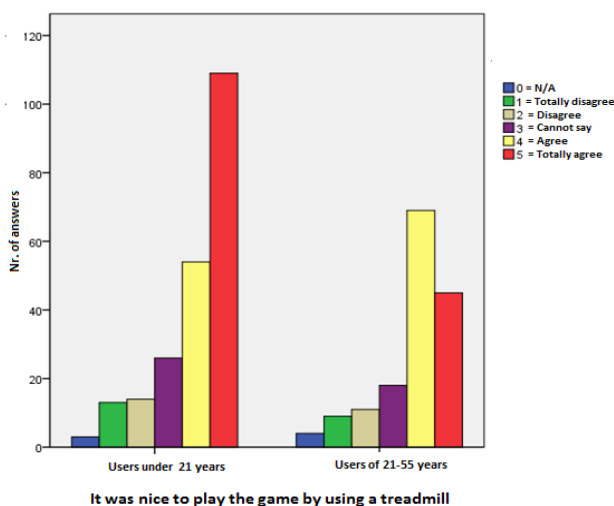


Fig. 7 The distribution of opinions of different age groups to the statement “It was nice to play the game by using a treadmill”.

in controlling the direction (head tilt) of movement. User feedback was again collected with an iSurvey questionnaire on iPad. The data of 381 users was analyzed. For the analysis, we divided the users into two age groups: users under 21 years and users between 21-55 years. Fig. 7 shows the number of different opinions to the statement: “It was nice to play the game by using a treadmill”. The majority of users enjoyed the exercising factor in the game play and this factor was more profound with people under 21 years.

Athene Exergaming for rehabilitation: the last pilot

examination was to explore the usability and possibilities of Athene Exergaming in the rehabilitation and activating elderly people. Our light demo version of Athene Exergaming consisted of a restorator bike for legs that was used to control the speed, Kinect motion controller that was used to choose the direction in the crossroads (hand gesture), ACD card that connected the restorator bike with Athene software, PC and a video projector. In the collaboration with Sendai University, we conducted a study in which 12 elderly Japanese subjects participated in the examination. In the exergaming, physical and cognitive tasks were used in applications Explore the City of Kajaani (3 minutes), Banana Hunting (3×2.5 minutes) and Wandering in Finnish Forest Environment (3 minutes as a bonus task for five participants). The data have not been analyzed yet, but based on the observations we made during the experiments, we noticed the interest and enthusiasm of our subjects towards exercising in the virtual environments.

6. Discussion

Exergames have good prospects to motivate people from all age groups to be more physically active. They are often perceived as fun to play, but the idea behind exergames also promotes a healthier lifestyle. Sedentary people may find joy in moving through the gameplay. In addition to the positive effects on physical activity, it is also important to consider the positive effects on the mental side of the people, demonstrated in several publications mentioned above.

Exergaming, especially with features that allow the users also to travel virtually, can bring fascinating experiences for many people. There are several places in the world that are too dangerous to visit. The climate can be too hot or polluted for exercising outdoors. In urban cities, the nature is just too far for many people to reach. Exercising in virtual environments may bring people a unique experience that is realistic, but without great deal of trouble.

Exergaming may also provide new tools for elite sports training and coaching. More research on exergaming and its possibilities should be carried out. For example, research on the correlation in the exercising between the real environment and the virtual environment should be carried out. Our preliminary results on positive correlations indicate that exercise in virtual environments could be used in elite athlete's training.

The exergaming industry is still small and but in its early phase, many interesting products for different purposes can be found and new products are created with increasing pace. Athene Exergaming takes an advantage of the existing technologies and equipment. What makes a difference to the other similar products on the market is the innovative way of combining existing exercising and rehabilitation devices with the virtual environment, application of games, advanced motion control and immersive visual systems and wall structures. Also, the Unity 3D game engine provides an ideal platform to apply the software for developing more game content for different target groups, for example.

In April 2014, Athene Exergaming was awarded as the second best innovation in the world wide Leading Trade Fair of Fitness, Wellness and Health (FIBO). Positive feedback from different pilots and success in FIBO innovation competition has encouraged the developmental work of the whole team for new endeavors. The Athene Exergaming will be launched in the markets in the fall 2014 by a spin-off company from the university.

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