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Immotion - Exergame for Warm Up Guidance and Motivation

Masterarbeit im Fach Informatik
Master's Thesis in Computer Science
von / by

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begutachtet von / reviewers

Saarbrücken, March 2018

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Saarbrücken, March 2018 Marko Vujić

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 fitness only. In this thesis, we designed an exergame for warm up guidance and motivation. This exergame is designed 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 and would improve motivation to engage in warm up procedures more often. By making the game interactive and appealing, with intervals that last as long as the player chooses to, the warm up procedure undergoes a shift from a repetitive and tiresome activity to an entertaining and challenging necessity. In order to evaluate our exergame, we conduced a user study comparing warm up procedure without a game to a warm up procedure with two versions of the game: one using the Kinect sensor, and one displayed on a screen. The usage of the exergame, with or without the Kinect sensor showed a small but statistically significant increase in exercise performance relative to the non-gaming condition, with the screen condition faring slightly better than the Kinect condition. The exergame showed a significant increase in user motivation and enjoyment when compared to the non gaming condition, with the Kinect condition found to be slightly more motivating than the screen condition.

Acknowledgements

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Chapter 1

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 centered design methodology has been 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 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.

1.1 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 []. 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 [**?**], 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 []. Researchers in [] 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 for warm up guidance and motivation.

1.2 The Context of Use

There exist 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 [cite wifit and stuf]. 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 [19, 21] although often avoided by multitude of athletes [27], 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 centers before any arduous sports activity. Additionally, we target individuals, above all amateur athletes, who do not know how to perform a proper warm up routine before the subsequent sport activity. Lastly, we design our exergame so the movements required to be executed by the player are intuitive and do not require additional explanation nor previous exercise knowledge.

1.3 Overview of the Development Phases

The development of the Immotion exergame consisted of three primary phases which are according to the well accepted UCD development phases outlined in the previous section and depicted in Figure 1.1:

- 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 1.1 will be further detailed.

FIGURE 1.1: Overview of the development iterations

1.3.1 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.
As previously pointed out, 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+) [31] 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 []. 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.

1.3.2 Prototype 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.

1.3.2.1 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 XX [] and projected on a wall using XX projector. In figure 1.2 we outline the relationship of the game, software, and hardware equipment.

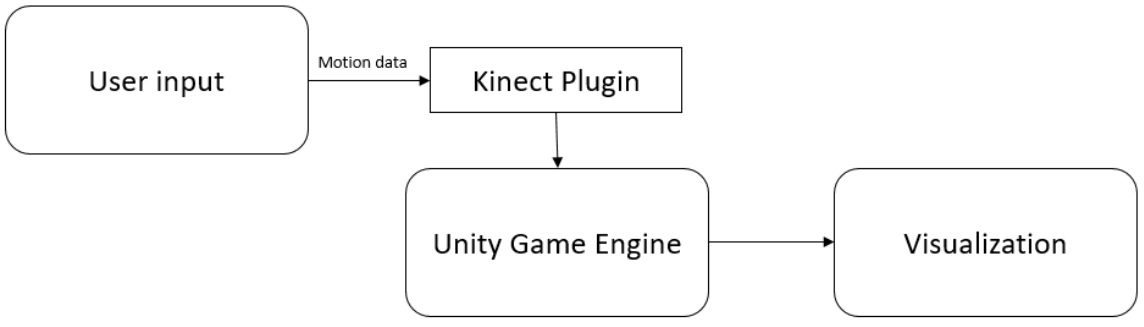


FIGURE 1.2: Hardware and Software supporting the prototype exergame

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 1.3 depicts the usage of the prototype version of the Immotion exergame during one of our final tests.

FIGURE 1.3: Interacting with the prototype version of the Immotion exergame

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

1.3.2.2 Gamification Elements

In order to create an immersive game environment that will shift users' focus from the exertion of the exercise, we also employ few game *mechanics*. Werbach and Hunter report that mechanics provide the "*basic processes that drive the action forward and generate player engagement*" [12]. For the prototype version of the Immotion exergame, the most important mechanics was *Feedback*.

1.3.2.3 Feedback

As pointed out in Chapter **??**, 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 [12]. 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 receives the feedback using different gamification components that will be further detailed.

1.3.2.4 Gamification Components

Points

According to Zichermann and Cunningham [65] 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 1.4.

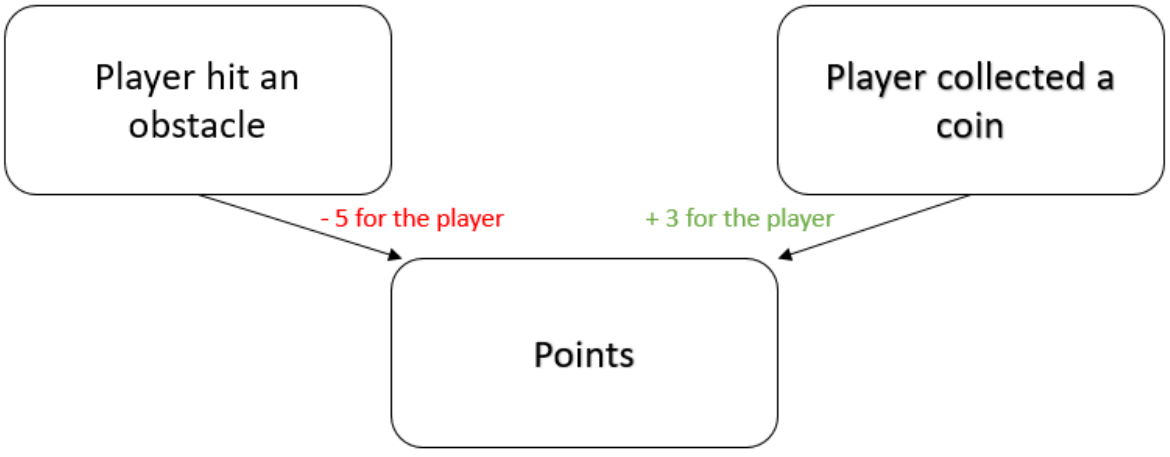


FIGURE 1.4: Earning and loosing point in the prototype version of the exergame

As per Figure 1.4, 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 1.5.

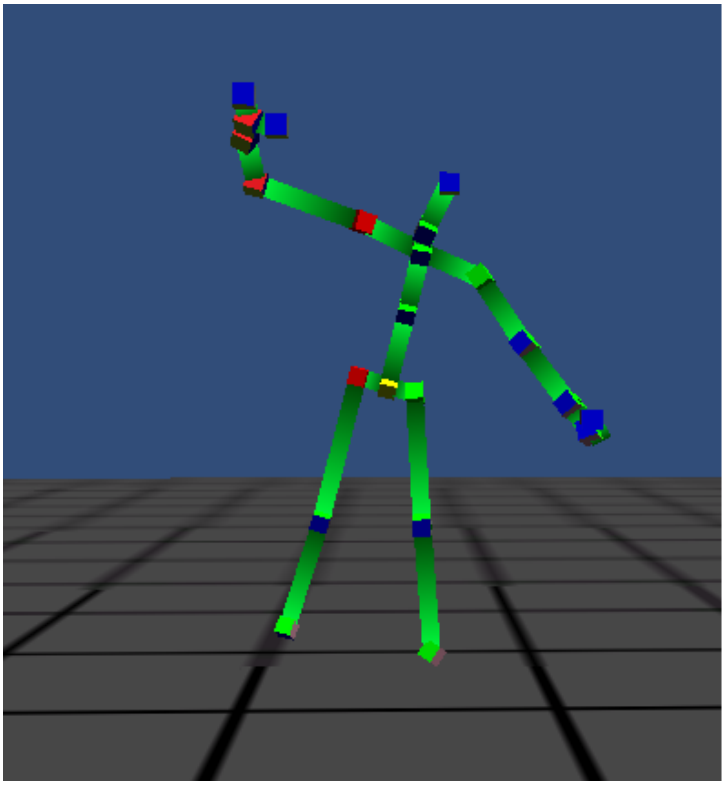


FIGURE 1.5: The avatar used in the prototype game.

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 is hit by the avatar. This is 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 players 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.

1.3.3 Game Scenes

Figure 1.6 shows the scenes from the prototype version of the exergame. The prototype has been pilot-tested with few student volunteers. During the pilot testing, the interaction with the exergame has been recorded for further analysis and evaluation [link yt].

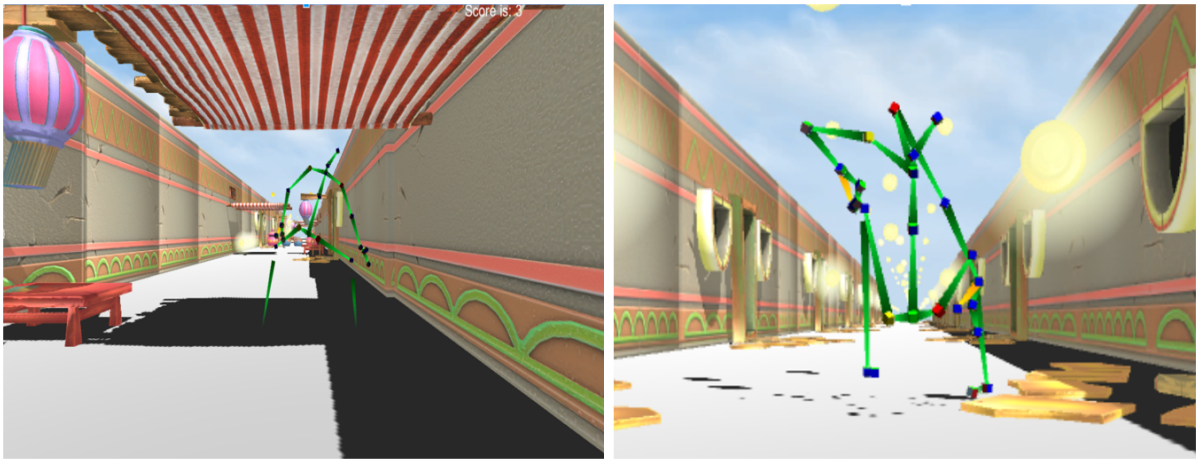


FIGURE 1.6: Game scenes from the prototype version of the exergame

In the next chapter, we present the evaluation of the prototype exergame. Through a survey, we evaluated which features of the gamified system are appreciated the most and which the least, and hence can be removed or improved in the final exergame release.

Chapter 2

Study Design

The main goals of this thesis were to develop an exergame which can be used for warm up routine before more strenuous physical activity and to 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 present the obtained results.

2.1 Description of the Experiment

This section describes the evaluation of the second version of the Immotion exergame. For this purpose, an approach was adopted that uses a mixture of different tools and user study methods. During this period, data has been logged, surveys have been conducted, and interviews undertaken. Similarly to the evaluation of the prototype exergame (Chapter 2), the obtained results are analyzed 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.

2.1.1 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 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 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 gamified solution in the given context, the user base is divided into two groups: *experimental group* and *control group*. The first, experimental group, is the one that interacts with the exergame directly. Contrarily, the control group is presented with the video of a coach (professional) who guides the participant through the warm up routine. This division allows 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.

2.1.1.1 Hypotheses

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

1. The exergame itself is sufficient for guiding the player through a proper warm up procedure with correct movements.

2. After the warm up routine is completed using the exergame, the player reached a significantly higher increase in ROM.

3. Participants had a more positive perceived warm up experience when using the exergame compared to the participants not using the exergame.

2.1.1.2 Apparatus

The experiment was conducted in the laboratory room in DFKI on (add date). The laboratory is presented in Figure 2.1.

FIGURE 2.1: Laboratory.

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.
- 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 heart rate data.
- Goniometer used for measuring participants' ROM.

The Kinect motion sensor has been placed in front of the display panel facing the participant playing the exergame. The participant was instructed to keep at least 2 meter distance from the sensor during the gameplay. This distance was the most optimal in order to ... The sensor is presented in Figure 2.2.

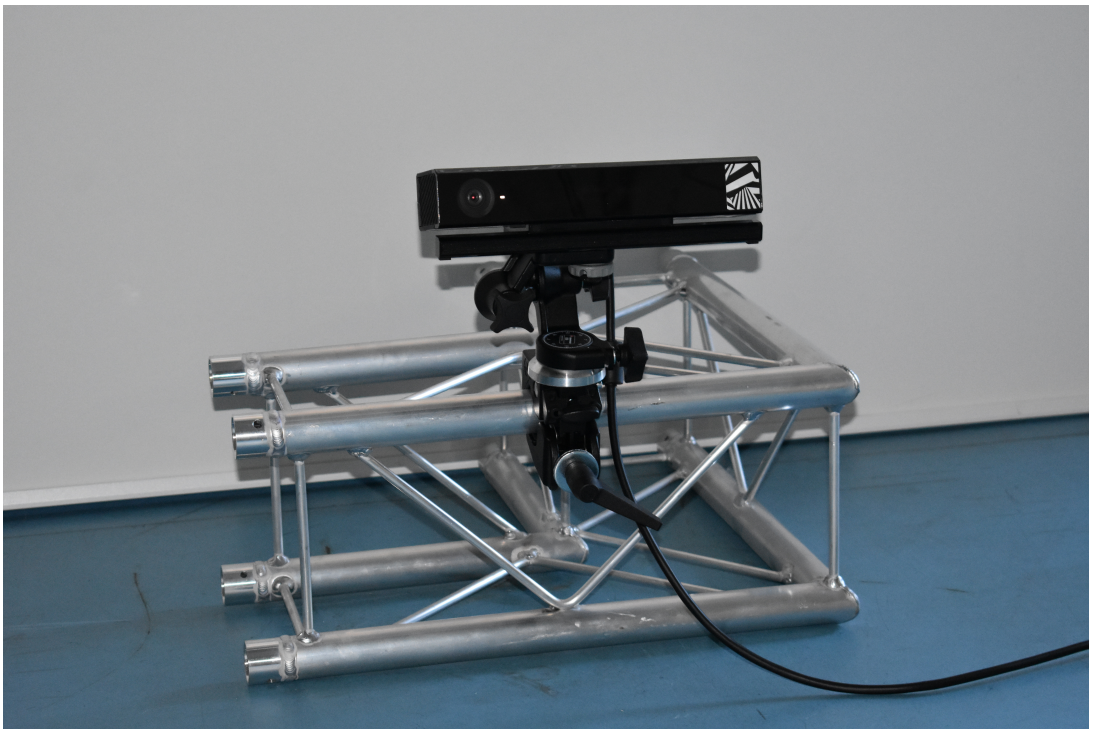


FIGURE 2.2: Kinect motion sensor.

We used XXX beamer in order to project the exergame to the display. The beamer, showed in Figure 2.4 was placed above the user so it did not interfere with the game flow. The desktop set up that consisted of XXX is presented in Figure 2.3.

2.1.2 Methods

In this section we outline the methodology adopted for the Immotion exergame evaluation. For this purpose we utilize the traditional (moderated) usability test since it gives direct input on how real users use the system.

2.1.2.1 Participants

Demographic details of the participants to be added when the study is completed.
Total of n = X individuals participated in the study that has been conducted DATE in DFKI.

FIGURE 2.3: Desktop set up.

All participants were students from Saarland University. For recruiting participants, posters were distributed in print, and sent through social media and email (Appendix X). Each participant was given X euros for taking part in the study. All of the participants were amateur athletes who engage in some physical activity on average X 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 (Appendix X). TODO: This should be updated later with real data.

2.1.2.2 Conditions

First 20 participant who applied for the experiment have been accepted. These participants were sent a pre-test questionnaires (BSA-F, PARQ, and 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:

FIGURE 2.4: Projector.

1. Warming up with the exergame guiding through the warm up procedure, projected on a wall in front of the participant.
2. Warmin 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 conditions.

2.1.2.3 Control and Experiment Groups

The participants are assigned to each group based on the previously completed self-reported questionnaires. These questionnaires were sent to each participant and needed to be completed before the experiment. Based on the answers provided, each participant was assigned to either control or experiment group. The surveys assessed participants' perceived physical fitness level, warm up preferences, and previous exergames experience.

2.1.2.4 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 [91]. The individual response patterns were used in order to assess if participants were physically able to perform the warm up session.
- Demographic survey with included questions regarding warm up preferences, and previous exergame experience [Appendix].
- *Physical activity screening.* Pre-study physical activity levels have been assessed with a standardized questionnaire Bewegungs und Sportaktivität Fragebogen (BSA-F) [92]. 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 (TODO: discuss the time frame) 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 [93]. 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. All the participants received standardized instructions and were encouraged to focus upon their overall (wholebody) perceptions of exertion.
- *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) [94].
- *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 [95].
- *System usability.* For assessing the exergame's instrumental qualities (e.g. controllability, effectiveness, learnability), the System Usability Scale (SUS) has been used.
- *Enjoyment of digital games* In order to measure the enjoyment of digital games the Game Experience/Engagement Questionnaire (GEQ) has been utilized. It is a general questionnaire with the goal of being able to be applied to any game regardless of genre or mechanics in order to measure their users' experience.

(TO BE DISCUSSED: Sport oriented questionnaire (SOQ), Task and Ego Orientation in Sport Questionnaire (TEOSQ), AttrakDiff, User Experience, Exergame Experience questionnaires are also used in some studies.)
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. (TODO)
- *Heart rate.* The participant's heart rate data has been captured and the measured during the warm up procedure using Microsoft Band.
- *Distance.* The overall distance the participants' moved during the warm up routine was measured using Microsoft Kinect.

2.1.2.5 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, avoided obstacles and collected coins. Based on the data and feedback gathered from the first study, we limited the movements the participants need 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 no prior exercise knowledge or experience were required. 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 and did not interact with the gamified system were required to perform the same set of general movements. However, participants in this group had to follow a video that was projected on the wall in front of them. The video was a recording of a professional (coach) who guided the participants through the warm up routine. By following the video, and thus the coach, the participants were required to execute the same movements as the participant in the experiment group who interacted with the exergame.

2.1.2.6 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 is set up. The Kinect sensor is placed in a correct position and turned on. The PC running the software is started and the projector is enabled. In each session only one participant was present and guided by the researcher. The activities each participant followed are:

- 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 for the following joints: (TODO decide which joint will be measured).
- After the measurements are completed, the participant rests.
- 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 experimental group, the game starts with the start scene where the participant enters his or her name. After 5 seconds, the game proceeds with scenes in which the participant performs 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. During this period the researcher assesses the ROM of the participant.

- After taking the ROM measures, the sensors are removed.
- The participant completes the post-test surveys .

2.1.2.7 Independent and Dependent Variables

Include exactly how you intend to measure each dependent variable. Independent variables are the things you manipulate or control for, such as design's you are testing or the ages of the respondents. Dependent variables are the things you measure, such as success rate, number of errors, user satisfaction, completion time, and many more. Have s clear idea what do you manipulate - independent variables, and what do you want to measure - dependent variables. The most interesting is the intersection - is one design results in a higher task success rate than other.

Independent and dependent variables can be measured by 4 types of data: nominal, ordinal, interval, and ratio. Nominal (categorical) data: groups or categories. Mac vs Windows users, male vs female. These are independent variables, that allows you to segment data by these different groups. Nominal data also includes dependent variables like task success, number of users who clicked link A instead B... Ordinal: ordered data - imdb. In user studies this comes from self-reported data. User states if someone is good better worse... These are relative rankings. You report it by frequencies: for example 40 percent said it is good.

2.1.3 Problems/Limitations - Threats to Validity

Describe any problems/limitations encountered that will help other researchers avoid or account for them if they decide to replicate your experiment.

2.2 Results

This section is an objective report on what the numbers show. You should not try to interpret the meaning of the numbers in this section. Some of the things you may do here are: report means and standard deviations in neat tables indicate the statistics used and levels of significance include graphs, plots, histograms, etc that tell a story about the actual figures obtained Only critical raw data and summary statistics should be included in the actual report. However, you must keep all your raw data in a separate archival report, should anyone (a reviewer in the case of real scientific reporting) need more detail than is provided in the paper.

2.3 Discussion

Interpret the results. Although you should still try to be as objective as possible, the discussion section should illuminate your critical thinking about the results. Explain what the statistics mean, account for anomalies, and so on.

2.3.1 Interpretation of Results

Discuss what you believe the results really mean. For example, if you find a significant difference for some effect, what does that mean to the hypothesis? Is the different seen an important one?

2.3.2 Relation to other works

How do the results you've obtained relate to other research findings?

2.3.3 Impact for practitioners

As computer scientists, we are particularly concerned with the implications of our findings on practitioners. Should existing interface constructs be designed differently or used in a new context? Do you have suggestions for new designs? How can the findings be generalized?

2.3.4 Critical reflection

Critical reflection is one of the key foundations of science. You should criticize your work (constructively, if possible), indicate possible flaws, mitigating circumstances, the limits to generalization, conditions under which you would expect your findings to be reversed, and so on.

2.3.5 Research agenda

The best experiments suggest new avenues of exploration. In this section, you should reflect and refine your hypotheses, describe new hypotheses, and suggest future research, ie research that you would do if you continued along this path.

2.4 Conclusions

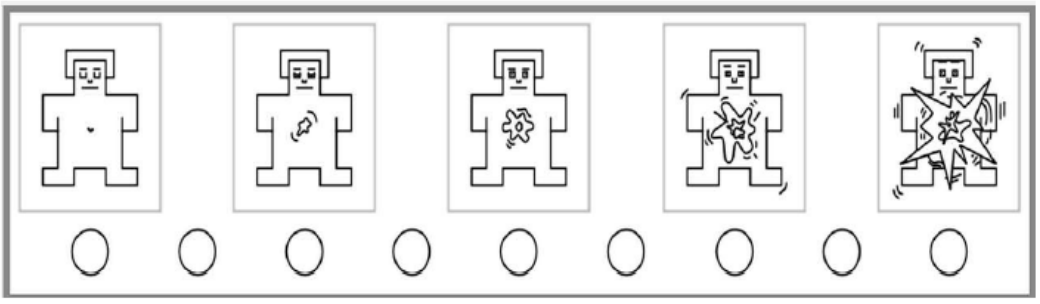
Summarize the report, and speculate on what is to come. Acknowledgements. This section should give thanks to the major people (supervisors, associates) and organizations (sponsoring agencies, funders) that helped you. For example, I would like to thank Ben Shneiderman, whose report framework was used to build this one.

Appendices

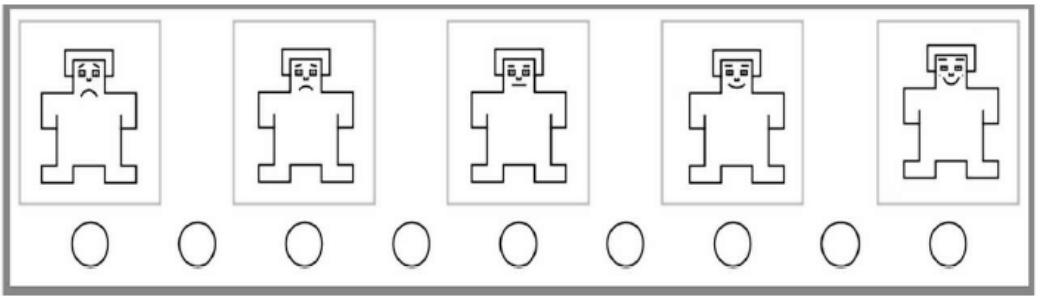
Appendix A

Self-Assessment Manikin Scale

1. The scale rates the arousal of your present feeling. At the low end of the arousal scale are feelings like relaxed, calm, sluggish, dull, sleepy, and unaroused. At the high end of the scale are feelings like stimulated, excited, frenzied, jittery, wide awake, and aroused.



2. The scale rates the valence of your present feeling. At the low end of the valence scale are feelings like unhappy, annoyed, unsatisfied, melancholic, despairing, and bored. At the high end are feelings like happy, pleased, satisfied, contented, hopeful, and relaxed.



Bibliography

[1] H. O. Mayr, S. Zaffagnini, *et al.*, *Prevention of Injuries and Overuse in Sports*. Springer, 2015.

[2] "Fitness app popularity." `https://www.spaceotechnologies.com/fitness-apps-gaining-popularity-hire-iphone-app-developer-now/`. Accessed: 2017-12-20.

[3] J. Hamari, J. Koivisto, and H. Sarsa, "Does gamification work?–a literature review of empirical studies on gamification," in *System Sciences (HICSS), 2014 47th Hawaii International Conference on*, pp. 3025–3034, IEEE, 2014.

[4] S. Deterding, D. Dixon, R. Khaled, and L. Nacke, "From game design elements to gamefulness: defining gamification," in *Proceedings of the 15th international academic MindTrek conference: Envisioning future media environments*, pp. 9–15, ACM, 2011.

[5] E. L. Deci and R. M. Ryan, "Promoting self-determined education," *Scandinavian journal of educational research*, vol. 38, no. 1, pp. 3–14, 1994.

[6] R. M. Ryan and E. L. Deci, "Intrinsic and extrinsic motivations: Classic definitions and new directions," *Contemporary educational psychology*, vol. 25, no. 1, pp. 54–67, 2000.

[7] M. Csikszentmihalyi, "Flow and the psychology of discovery and invention," *New Yprk: Harper Collins*, 1996.

[8] J. Nakamura and M. Csikszentmihalyi, "The concept of flow," in *Flow and the foundations of positive psychology*, pp. 239–263, Springer, 2014.

[9] "Intrinsic and extrinsic motivation in gamification." `http://gamification-research.org/2014/08/flow/`. Accessed: 2017-02-20.

[10] "Bartle's taxonomy of player types." `https://gamedevelopment.tutsplus.com/articles/bartles-taxonomy-of-player-types-and-why-it-doesnt-apply-to-everything--gamedev-4173`. Accessed: 2017-03-10.

[11] G. F. Tondello, R. R. Wehbe, L. Diamond, M. Busch, A. Marczewski, and L. E. Nacke, "The gamification user types hexad scale," in *Proceedings of the 2016 Annual Symposium on Computer-Human Interaction in Play*, pp. 229–243, ACM, 2016.

[12] K. Werbach and D. Hunter, *For the win: How game thinking can revolutionize your business*. Wharton Digital Press, 2012.

[13] D. E. Warburton, C. W. Nicol, and S. S. Bredin, "Health benefits of physical activity: the evidence," *Canadian medical association journal*, vol. 174, no. 6, pp. 801–809, 2006.

[14] W. van Mechelen, "The severity of sports injuries," *Sports medicine*, vol. 24, no. 3, pp. 176–180, 1997.

[15] P. Edouard, N. Feddermann-Demont, J. M. Alonso, P. Branco, and A. Junge, "Sex differences in injury during top-level international athletics championships: surveillance data from 14 championships between 2007 and 2014," *British journal of sports medicine*, vol. 49, no. 7, pp. 472–477, 2015.

[16] N. Lefevre, Y. Bohu, S. Herman, S. Klouche, and E. Servien, "Major causes of sports injuries," in *Prevention of Injuries and Overuse in Sports*, pp. 15–25, Springer, 2016.

[17] F. Fischer, J. Menetrey, M. Herbort, P. Gföller, C. Hepperger, and C. Fink, "Causes of overuse in sports," in *Prevention of Injuries and Overuse in Sports*, pp. 27–38, Springer, 2016.

[18] M. Pećina and I. Bojanić, *Overuse injuries of the musculoskeletal system*. CRC Press, 1993.

[19] D. Bishop, "Warm up i," *Sports medicine*, vol. 33, no. 6, pp. 439–454, 2003.

[20] D. Bishop, "Warm up ii," *Sports Medicine*, vol. 33, no. 7, pp. 483–498, 2003.

[21] F. G. Shellock and W. E. Prentice, "Warming-up and stretching for improved physical performance and prevention of sports-related injuries," *Sports Medicine*, vol. 2, no. 4, pp. 267–278, 1985.

[22] J. Karvonen, "Importance of warm-up and cool down on exercise performance," in *Medicine in Sports Training and Coaching*, pp. 189–214, Karger Publishers, 1992.

[23] K. Woods, P. Bishop, and E. Jones, "Warm-up and stretching in the prevention of muscular injury," *Sports Medicine*, vol. 37, no. 12, pp. 1089–1099, 2007.

[24] A. Hedrick, "Exercise physiology: Physiological responses to warm-up.," *Strength & Conditioning Journal*, vol. 14, no. 5, pp. 25–27, 1992.

[25] M. R. Safran, M. A. V. Seaber, and W. E. Garrett Jr, "Warm-up and muscular injury prevention an update," *Sports Medicine*, vol. 8, no. 4, pp. 239–249, 1989.

[26] D. V. Knudson, "Warm-up and flexibility," *Chandler TJ, Brown LE. Conditioning for Strength and Human Performance. Philadelphia, PA: Lippincott-Williams & Wilkins*, 2008.

[27] A. J. Fradkin, B. J. Gabbe, and P. A. Cameron, "Does warming up prevent injury in sport?: The evidence from randomised controlled trials?," *Journal of Science and Medicine in Sport*, vol. 9, no. 3, pp. 214–220, 2006.

[28] M. A. Ladwig, "The psychological effects of a pre-workout warm-up: An exploratory study," *Journal of Multidisciplinary Research*, vol. 5, no. 3, p. 79, 2013.

[29] K. B. Fields, C. M. Burnworth, and M. Delaney, "Should athletes stretch before exercise?," *Chinese Journal of Sports Medicine*, vol. 26, no. 5, p. 626, 2007.

[30] D. Pereles, A. Roth, and D. Thompson, "A large, randomized, prospective study of the impact of a pre-run stretch on the risk of injury on teenage and older runners," 2012.

[31] "Fifa 11+." `http://f-marc.com/11plus/home/`. Accessed: 2017-12-21.

[32] N. C. Barengo, J. F. Meneses-Echávez, R. Ramírez-Vélez, D. D. Cohen, G. Tovar, and J. E. C. Bautista, "The impact of the fifa 11+ training program on injury prevention in football players: a systematic review," *International journal of environmental research and public health*, vol. 11, no. 11, pp. 11986–12000, 2014.

[33] A. J. Fradkin, T. R. Zazryn, and J. M. Smoliga, "Effects of warming-up on physical performance: a systematic review with meta-analysis," *The Journal of Strength & Conditioning Research*, vol. 24, no. 1, pp. 140–148, 2010.

[34] "Gamification examples given by badgeville.com." `https://badgeville.com/wiki/Gamification_Examples`. Accessed: 2017-01-25.

[35] "Gamification - applications." `https://en.wikipedia.org/wiki/Gamification#Applications`. Accessed: 2017-01-20.

[36] "Gamification examples." `http://www.enterprise-gamification.com/mediawiki/index.php?title=Gamification_Examples`. Accessed: 2017-01-27.

[37] "Nike +." `https://badgeville.com/wiki/Nike`. Accessed: 2017-01-27.

[38] "Deloitte leadership academy." `https://badgeville.com/wiki/case_studies#Deloitte`. Accessed: 2017-01-27.

[39] "My starbucks rewards." `https://badgeville.com/wiki/mystarbucksrewards`. Accessed: 2017-01-27.

[40] "My coke rewards." `https://www.mycokerewards.com/content/home.html`. Accessed: 2017-01-27.

[41] "Marketing gamification: Toyota turns charging your iphone into an epic game." `http://yukaichou.com/marketing-gamification/marketing-gamification-toyota-turns-charging-iphone-epic-game/`. Accessed: 2017-01-27.

[42] "Millenials." `https://en.wikipedia.org/wiki/Millennials`. Accessed: 2017-12-27.

[43] "Strava application and website for runners and cyclists." `https://www.strava.com/`. Accessed: 2017-12-20.

[44] "Foursquare official weboage." `https://foursquare.com/`. Accessed: 2017-12-21.

[45] "Codeacademy- gamafication." `http://www.enterprise-gamification.com/mediawiki/index.php?title=Codecademy`. Accessed: 2017-01-20.

[46] "Codeacademy- gamafication." `https://badgeville.com/`. Accessed: 2017-01-20.

[47] A. Marczewski, *Gamification: a simple introduction*. Andrzej Marczewski, 2013.

[48] "Gamify - a definition." `https://badgeville.com/wiki/Gamify/`. Accessed: 2017-01-20.

[49] K. M. Kapp, *The gamification of learning and instruction: game-based methods and strategies for training and education*. John Wiley & Sons, 2012.

[50] K. Salen and E. Zimmerman, *Rules of play: Game design fundamentals*. MIT press, 2004.

[51] J. Juul, *Half-real: Video games between real rules and fictional worlds*. MIT press, 2011.

[52] "Game design elements definition." https://en.wikipedia.org/wiki/Game_design#Design_elements. Accessed: 2017-01-20.

[53] K. Seaborn and D. I. Fels, "Gamification in theory and action: A survey," *International Journal of human-computer studies*, vol. 74, pp. 14–31, 2015.

[54] "Game design and gamification design." https://www.gamified.uk/2014/03/25/gamification-design-vs-game-design/. Accessed: 2018-01-20.

[55] A. E. Staiano and S. L. Calvert, "Exergames for physical education courses: Physical, social, and cognitive benefits," *Child development perspectives*, vol. 5, no. 2, pp. 93–98, 2011.

[56] R. Altamimi and G. Skinner, "A survey of active video game literature," *Journal of Computer and Information Technology*, vol. 1, no. 1, pp. 20–35, 2012.

[57] "Nintendo wii." https://en.wikipedia.org/wiki/Wii/. Accessed: 2017-12-20.

[58] M. J. Taylor and M. Griffin, "The use of gaming technology for rehabilitation in people with multiple sclerosis," *Multiple Sclerosis Journal*, vol. 21, no. 4, pp. 355–371, 2015.

[59] G. Barry, B. Galna, and L. Rochester, "The role of exergaming in parkinson's disease rehabilitation: a systematic review of the evidence," *Journal of neuroengineering and rehabilitation*, vol. 11, no. 1, p. 33, 2014.

[60] D. Webster and O. Celik, "Systematic review of kinect applications in elderly care and stroke rehabilitation," *Journal of neuroengineering and rehabilitation*, vol. 11, no. 1, p. 108, 2014.

[61] A. Matallaoui, J. Koivisto, J. Hamari, and R. Zarnekow, "How effective is "exergamification"? a systematic review on the effectiveness of gamification features in exergames," in *Proceedings of the 50th Hawaii International Conference on System Sciences*, 2017.

[62] K. Kiili and S. Merilampi, "Developing engaging exergames with simple motion detection," in *Proceedings of the 14th International Academic MindTrek Conference: Envisioning Future Media Environments*, pp. 103–110, ACM, 2010.

[63] E. A. Vandewater, M.-s. Shim, and A. G. Caplovitz, "Linking obesity and activity level with children's television and video game use," *Journal of adolescence*, vol. 27, no. 1, pp. 71–85, 2004.

[64] Y. Oh and S. Yang, "Defining exergames and exergaming," *Proceedings of Meaningful Play*, pp. 1–17, 2010.

[65] G. Zichermann and C. Cunningham, *Gamification by design: Implementing game mechanics in web and mobile apps.* " O'Reilly Media, Inc.", 2011.

[66] R. M. Ryan and E. L. Deci, "Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being.," *American psychologist*, vol. 55, no. 1, p. 68, 2000.

[67] E. L. Deci and R. M. Ryan, "The" what" and" why" of goal pursuits: Human needs and the self-determination of behavior," *Psychological inquiry*, vol. 11, no. 4, pp. 227–268, 2000.

[68] "The purpose of gamification." http://radar.oreilly.com/2011/04/gamification-purpose-marketing.html/. Accessed: 2017-12-20.

[69] R. L. Pardee, "Motivation theories of maslow, herzberg, mcgregor & mcclelland. a literature review of selected theories dealing with job satisfaction and motivation.," 1990.

[70] "Intrinsic and extrinsic motivation in gamification." `http://www.gamification.co/2011/10/27/intrinsic-and-extrinsic-motivation-in-gamification/`. Accessed: 2017-02-12.

[71] A. Broeck, M. Vansteenkiste, H. Witte, B. Soenens, and W. Lens, "Capturing autonomy, competence, and relatedness at work: Construction and initial validation of the work-related basic need satisfaction scale," *Journal of Occupational and Organizational Psychology*, vol. 83, no. 4, pp. 981–1002, 2010.

[72] R. J. Vallerand, "Intrinsic and extrinsic motivation in sport and physical activity," *Handbook of sport psychology*, vol. 3, pp. 59–83, 2007.

[73] W. Peng, J.-H. Lin, K. A. Pfeiffer, and B. Winn, "Need satisfaction supportive game features as motivational determinants: An experimental study of a self-determination theory guided exergame," *Media Psychology*, vol. 15, no. 2, pp. 175–196, 2012.

[74] H. Song, J. Kim, K. E. Tenzek, and K. M. Lee, "The effects of competition on intrinsic motivation in exergames and the conditional indirect effects of presence," in *annual conference of the International Communication Association, Singapore*, 2010.

[75] M. Csikszentmihalyi, "Finding flow," 1997.

[76] C. Flow, "The psychology of optimal experience," *Harper&Row, New York*, 1990.

[77] "Gamification 101, the psychology of motivation." `https://community.lithium.com/t5/Science-of-Social-blog/Gamification-101-The-Psychology-of-Motivation/ba-p/21864`. Accessed: 2017-02-27.

[78] M. Csikszentmihalyi, S. Abuhamdeh, and J. Nakamura, "Flow," in *Flow and the foundations of positive psychology*, pp. 227–238, Springer, 2014.

[79] J. Kowal and M. S. Fortier, "Motivational determinants of flow: Contributions from self-determination theory," *The Journal of Social Psychology*, vol. 139, no. 3, pp. 355–368, 1999.

[80] K. Kiili, "Evaluations of an experiential gaming model," *Human Technology: An Interdisciplinary Journal on Humans in ICT Environments*, 2006.

[81] J. Hamari and J. Koivisto, "Measuring flow in gamification: Dispositional flow scale-2," *Computers in Human Behavior*, vol. 40, pp. 133–143, 2014.

[82] M. Sillaots, "Achieving flow through gamification: A study on re-designing research methods courses," in *European Conference on Games Based Learning*, vol. 2, p. 538, Academic Conferences International Limited, 2014.

[83] S. A. Jackson and R. C. Eklund, "Assessing flow in physical activity: The flow state scale–2 and dispositional flow scale–2," *Journal of Sport and Exercise Psychology*, vol. 24, no. 2, pp. 133–150, 2002.

[84] N. Yee, "Motivations for play in online games," *CyberPsychology & behavior*, vol. 9, no. 6, pp. 772–775, 2006.

[85] "Multi-user dungeon." `https://en.wikipedia.org/wiki/MUD/`. Accessed: 2017-10-20.

[86] R. Bartle, "Hearts, clubs, diamonds, spades: Players who suit muds," *Journal of MUD research*, vol. 1, no. 1, p. 19, 1996.

[87] "50 gamification mechanics and elements." https://www.gamified.uk/user-types/gamification-mechanics-elements/. Accessed: 2017-03-20.

[88] R. Hunicke, M. LeBlanc, and R. Zubek, "Mda: A formal approach to game design and game research," in *Proceedings of the AAAI Workshop on Challenges in Game AI*, vol. 4, 2004.

[89] "Gamification course by prof. kevin werbach, coursera.org." https://www.coursera.org/learn/gamification/lecture/JPQNK/4-2-the-pyramid-of-elements. Accessed: 2017-02-20.

[90] E. D. Mekler, F. Brühlmann, K. Opwis, and A. N. Tuch, "Do points, levels and leaderboards harm intrinsic motivation?: an empirical analysis of common gamification elements," in *Proceedings of the First International Conference on gameful design, research, and applications*, pp. 66–73, ACM, 2013.

[91] S. Thomas, J. Reading, and R. J. Shephard, "Revision of the physical activity readiness questionnaire (par-q).," *Canadian journal of sport sciences*, 1992.

[92] R. Fuchs, S. Klaperski, M. Gerber, and H. Seelig, "Messung der bewegungs-und sportaktivität mit dem bsa-fragebogen: eine methodische zwischenbilanz," *Zeitschrift für Gesundheitspsychologie*, vol. 23, no. 2, pp. 60–76, 2015.

[93] G. Borg, *Borg's perceived exertion and pain scales.* Human kinetics, 1998.

[94] M. M. Bradley and P. J. Lang, "Measuring emotion: the self-assessment manikin and the semantic differential," *Journal of behavior therapy and experimental psychiatry*, vol. 25, no. 1, pp. 49–59, 1994.

[95] D. Kendzierski and K. J. DeCarlo, "Physical activity enjoyment scale: Two validation studies," *Journal of Sport and Exercise Psychology*, vol. 13, no. 1, pp. 50–64, 1991.