Universität des Saarlandes
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für Künstliche Intelligenz

ImMotion
Exergame for Warm Up Guidance

Masterarbeit im Fach Informatik
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von / by

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Saarbrücken, Saturday 4th August, 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.

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Chapter 1

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.

1.1 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 2), 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.

1.1.1 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.

1.1.1.1 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.

1.1.1.2 Apparatus

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

FIGURE 1.1: 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.

1.1.2 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.

1.1.2.1 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.

1.1.2.2 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.

1.1.2.3 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.

1.1.2.4 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.

1.1.2.5 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.

1.1.2.6 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 .

1.1.3 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.

1.2 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 1.2: 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.

1.2.1 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 **??** and Figure **??**. The detailed table with individual values for each measured joint can be found in Appendix XXX.

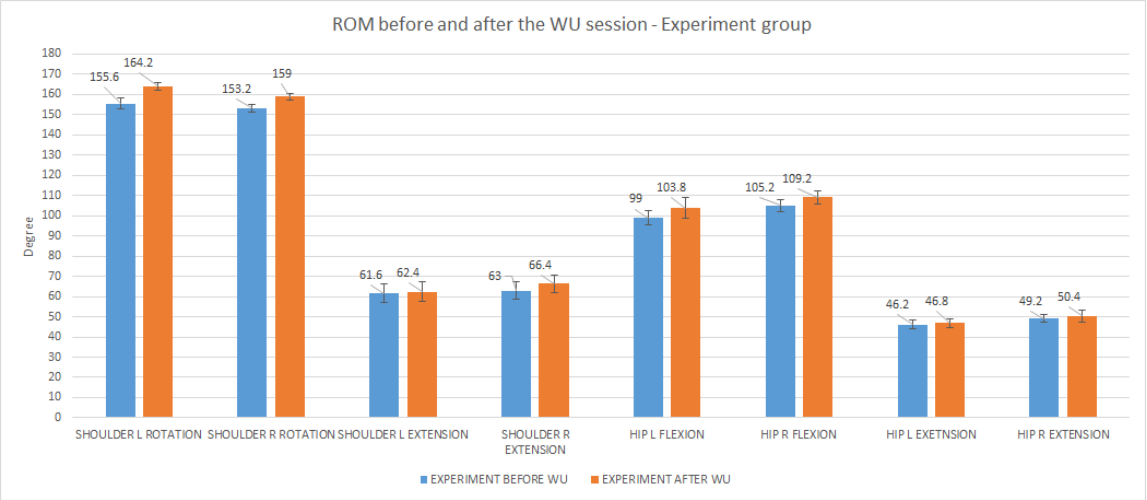

FIGURE 1.3: Summary of ROM results for the Experiment condition.

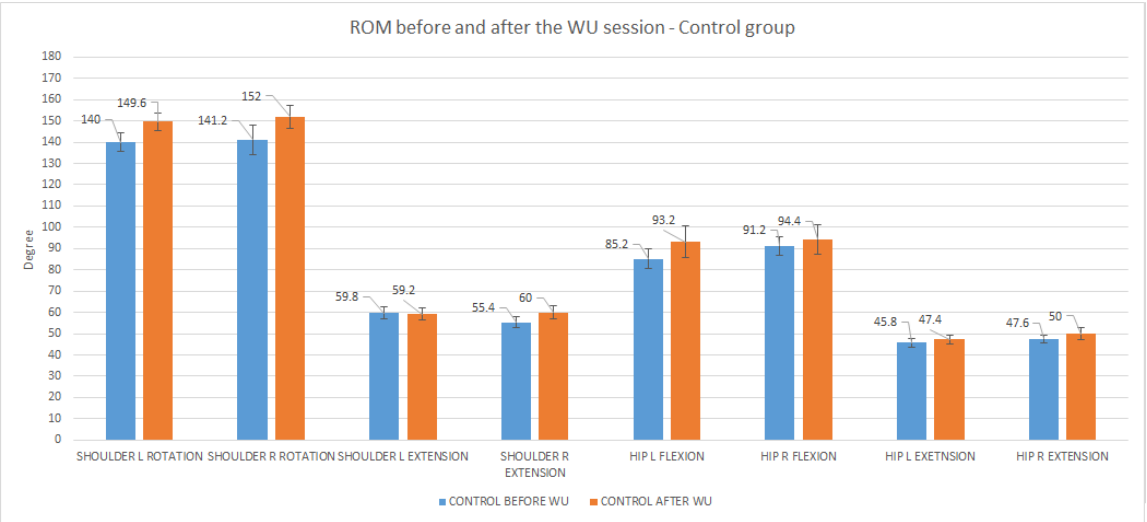

FIGURE 1.4: Summary of ROM results for the Control condition.

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.

1.2.2 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 **??**. Based on the results depicted in Figure **??** 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.

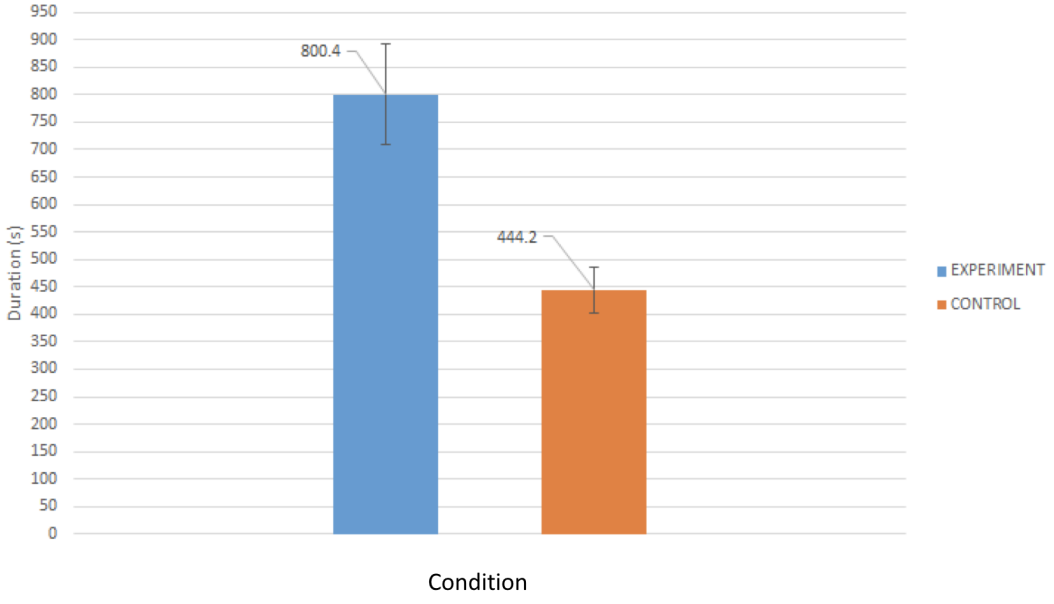

FIGURE 1.5: Average warm up duration with standard errors per condition.

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.

1.2.3 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 **??** ($M_{exp} = 0.919$, $SD_{exp} = 0.043$, $M_{con} = 0.84$, $SD_{con} = 0.050$). The bars presented in Figure **??** 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 **??** 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.

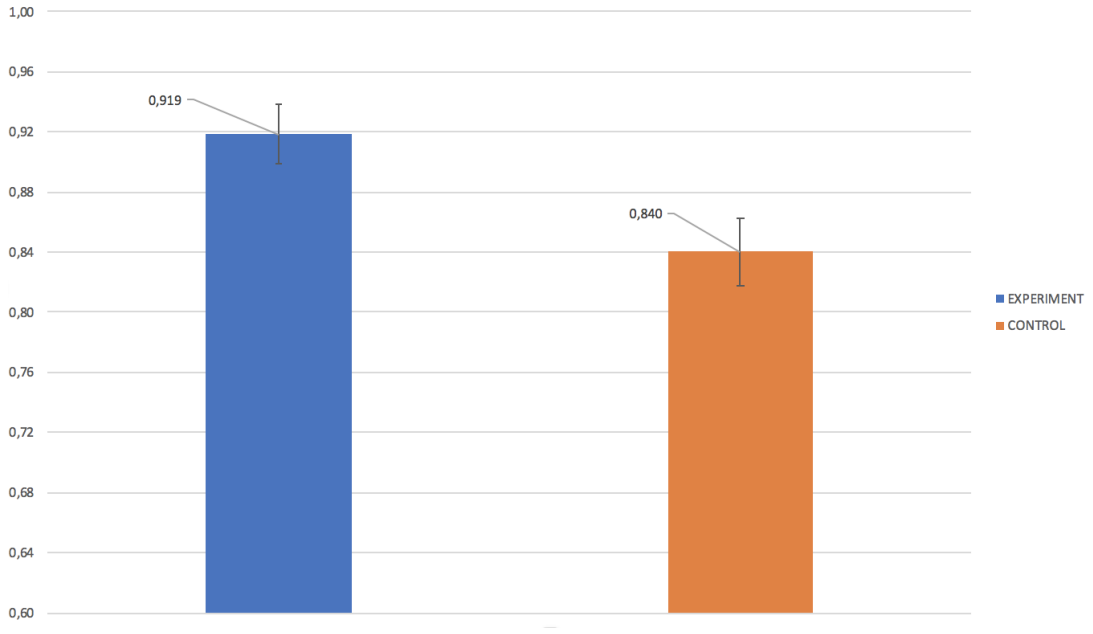

FIGURE 1.6: Average Maximum Relative heart rate per study group.

The individual heart rate data for each participant is depicted in Figure **??** [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 **??** is evident that the duration of the warm up session for the participants in the experiment group was significantly longer too.

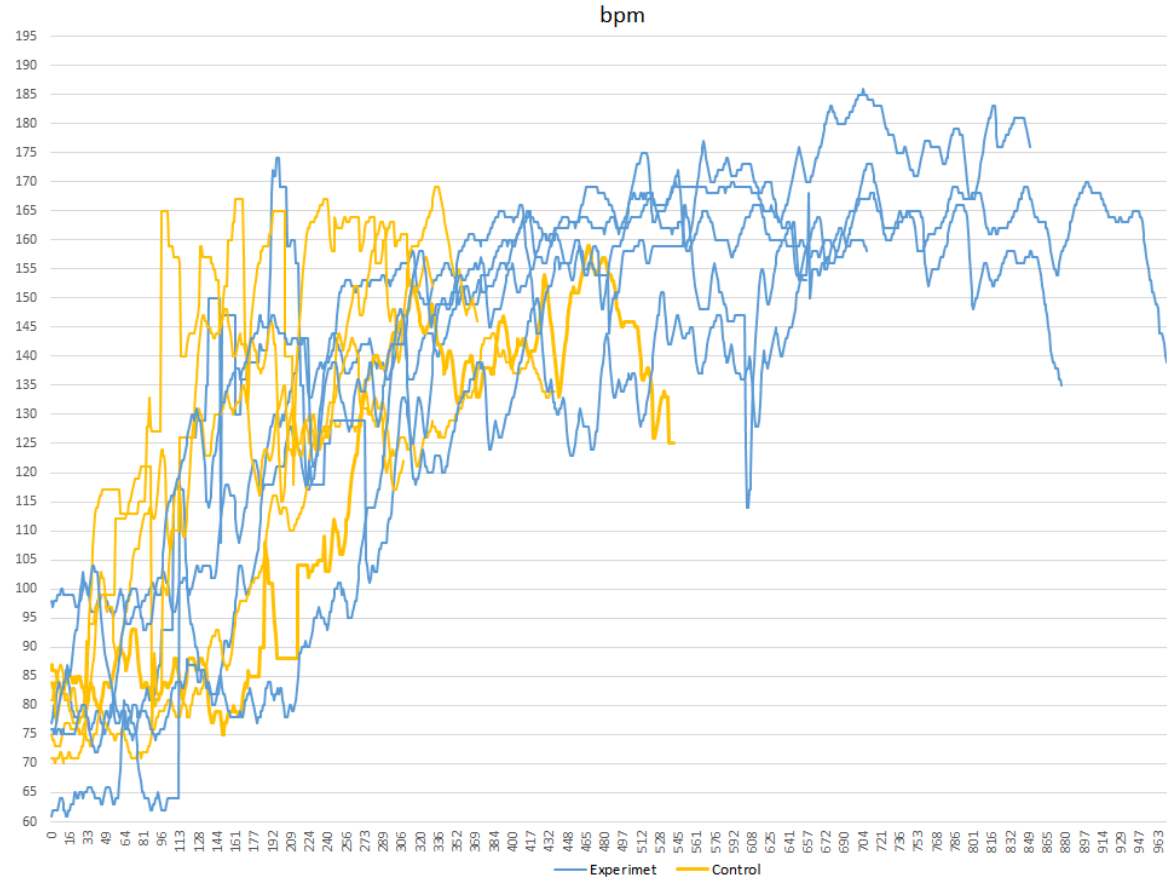

FIGURE 1.7: Heart rate data for each participant.

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}:

$$THR_{max} = 208 - (0.7 * age) \tag{1.1}$$

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:

$$HR_R = THR_{max} - R_{HR} \tag{1.2}$$

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

$$THR_{min} = HR_R * 0.5 + R_{HR} \tag{1.3}$$

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

$$THR_{mod} = HR_R * 0.7 + R_{HR} \tag{1.4}$$

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

$$THR_{int} = HR_R * 0.85 + R_{HR} \tag{1.5}$$

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 **??** 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 1.8: 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 **??** depicts the distribution of maximum heart rates participants reached during warm up session in both condition per exercise intensity zones.

Figure **??** 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.

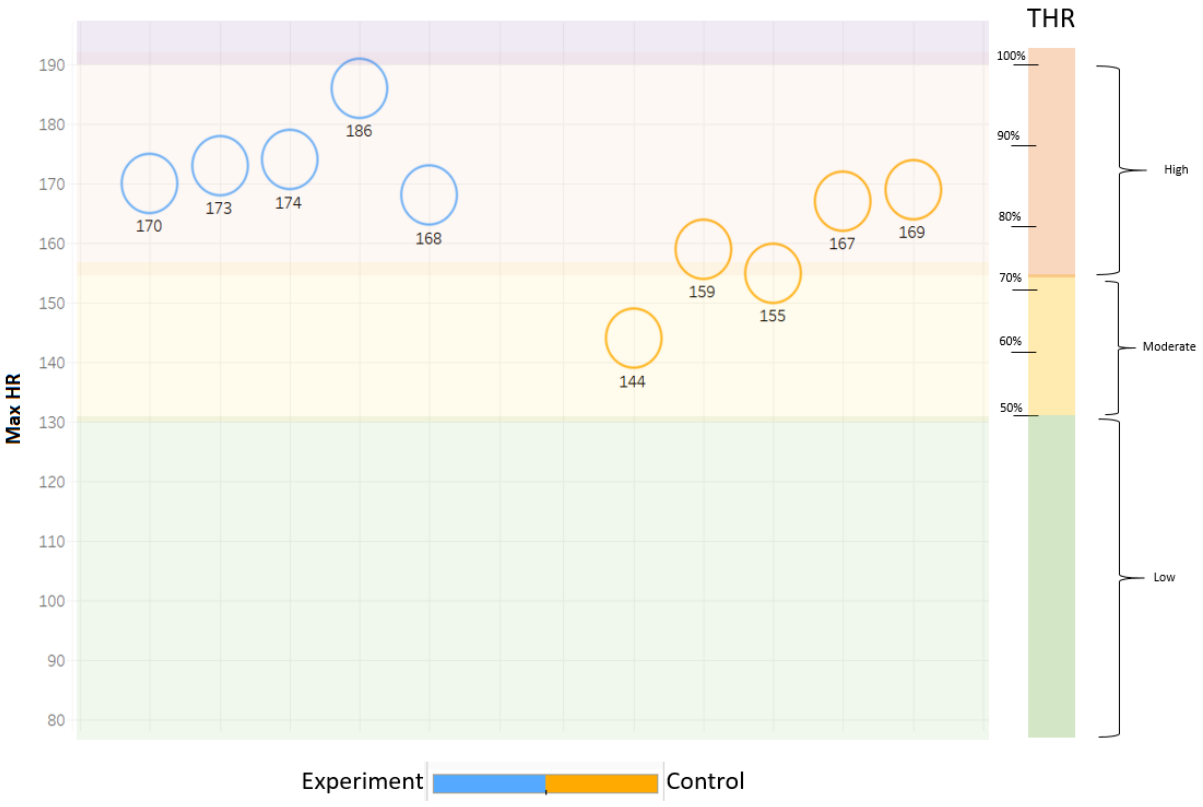

FIGURE 1.9: Target heart rate with exercise intensity for each participant

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.

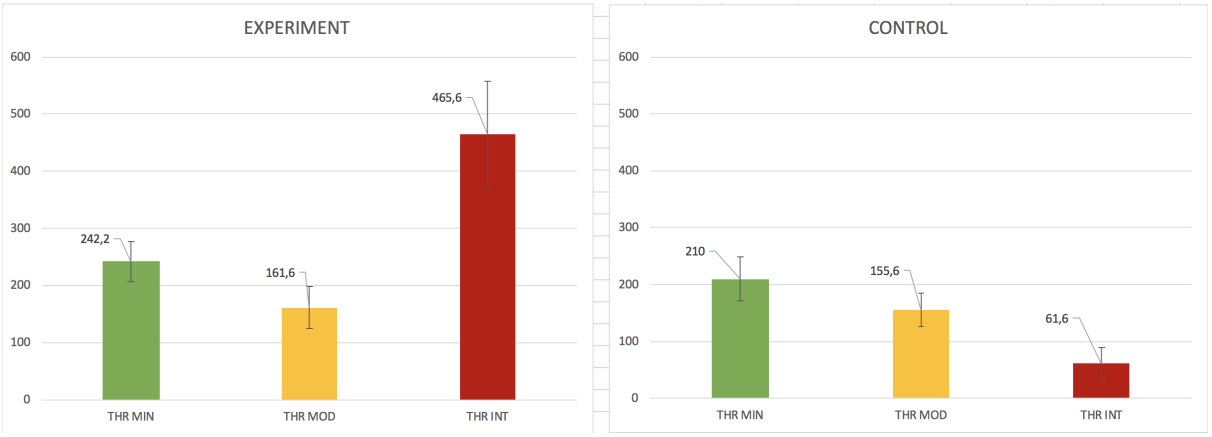

FIGURE 1.10: Average time spent in zones based on participants heart rate.

It can be observed from Figure **??** 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.

1.2.4 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 **??** 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.

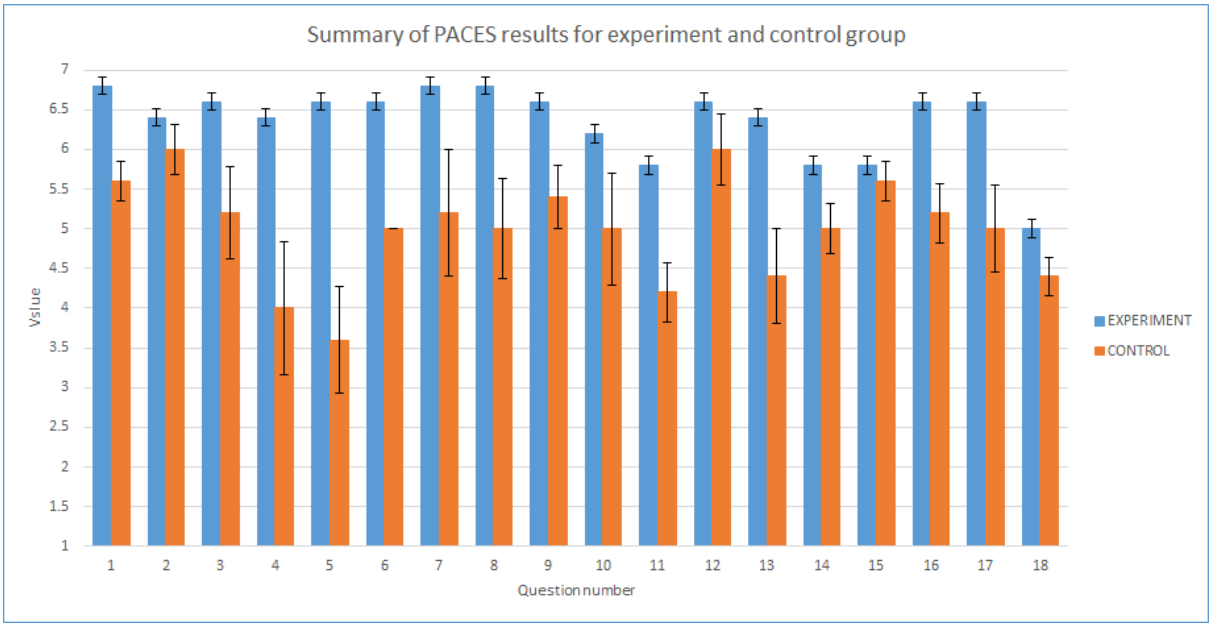

FIGURE 1.11: Summary of PACES results for the control and experiment group.

Figure **??** 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 $M = 114.4$ ($SD = 5.98, x_{max} = 125, x_{min} = 111$).

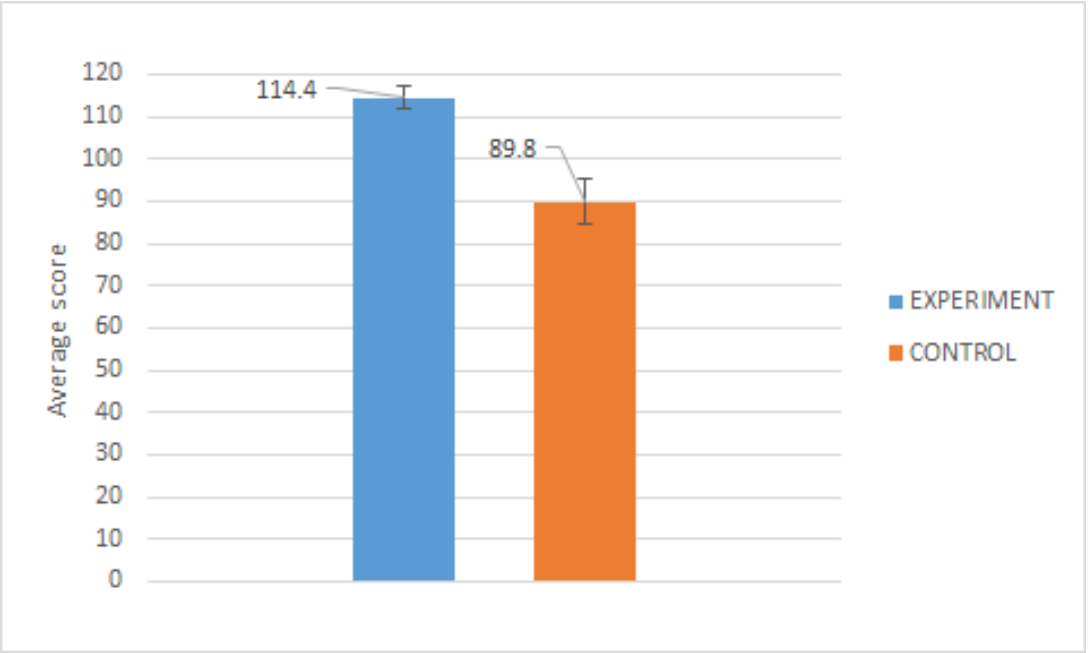

FIGURE 1.12: Average PACES scores for control and experiment condition.

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.

1.2.5 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 **??** 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.

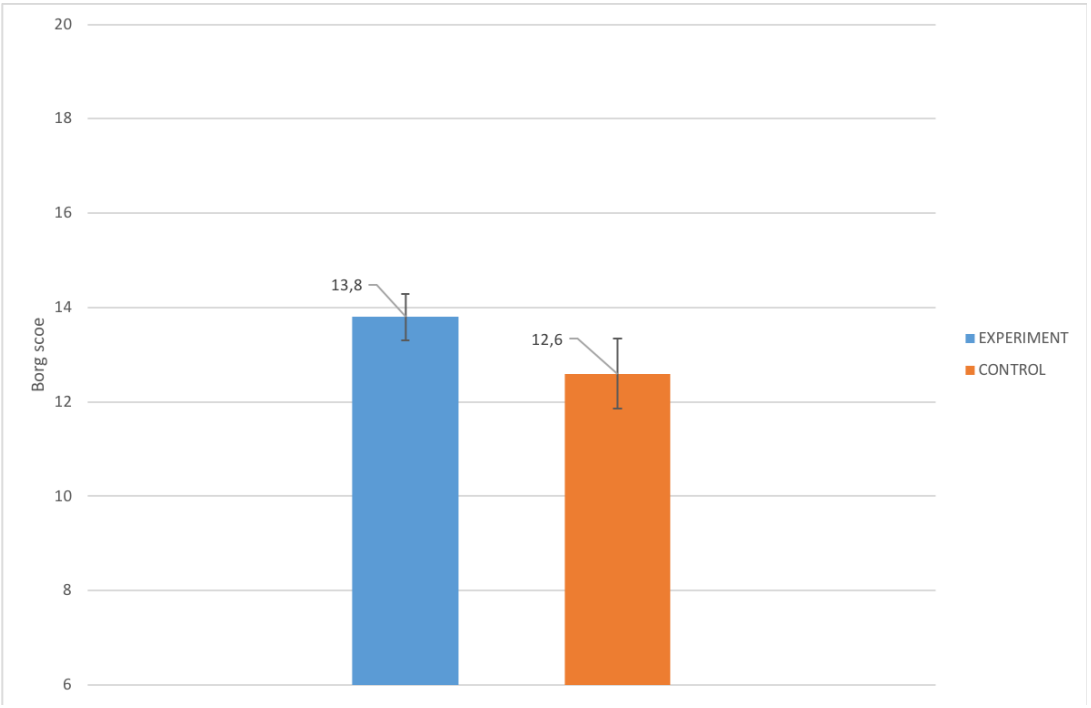

FIGURE 1.13: Summary of BORG results for control and experiment group.

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.

1.2.6 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 **??**. 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 **??** 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 **??**. 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.

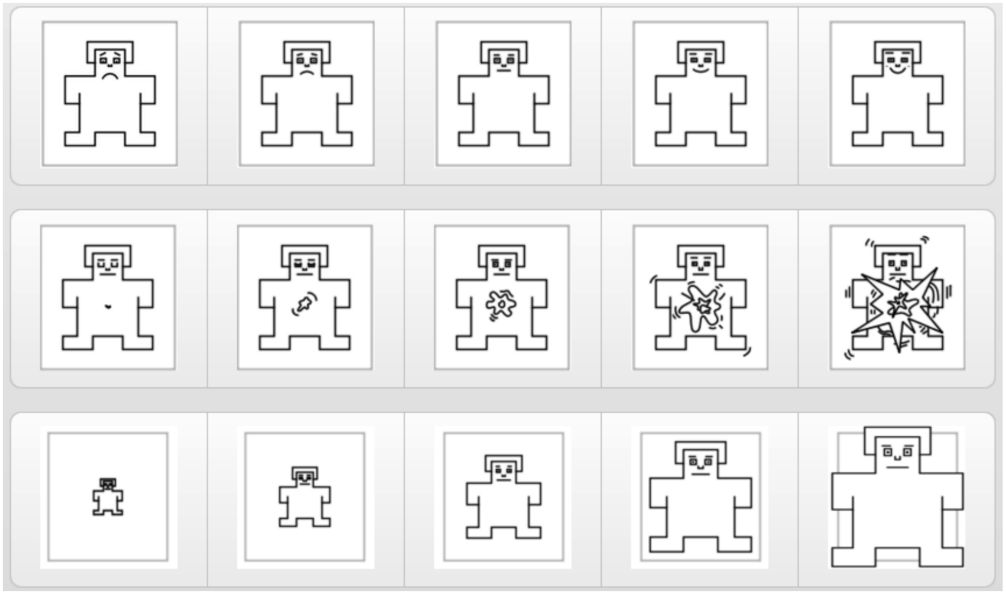

FIGURE 1.14: The Self-Assessment Manikin (SAM).

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.

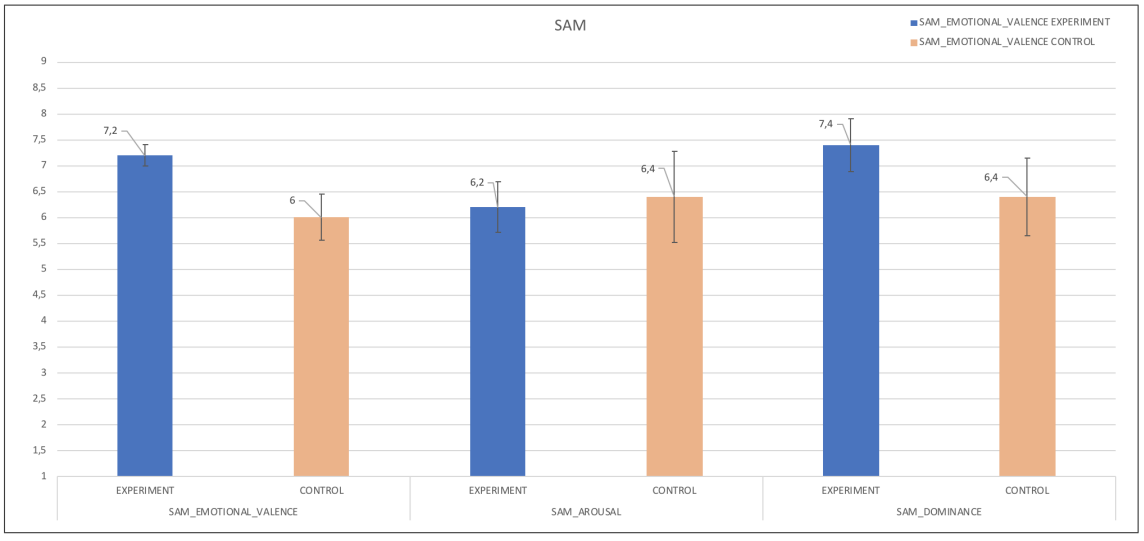

FIGURE 1.15: Summary of SAM results for control and experiment group.

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.

1.2.7 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 **??**. 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].

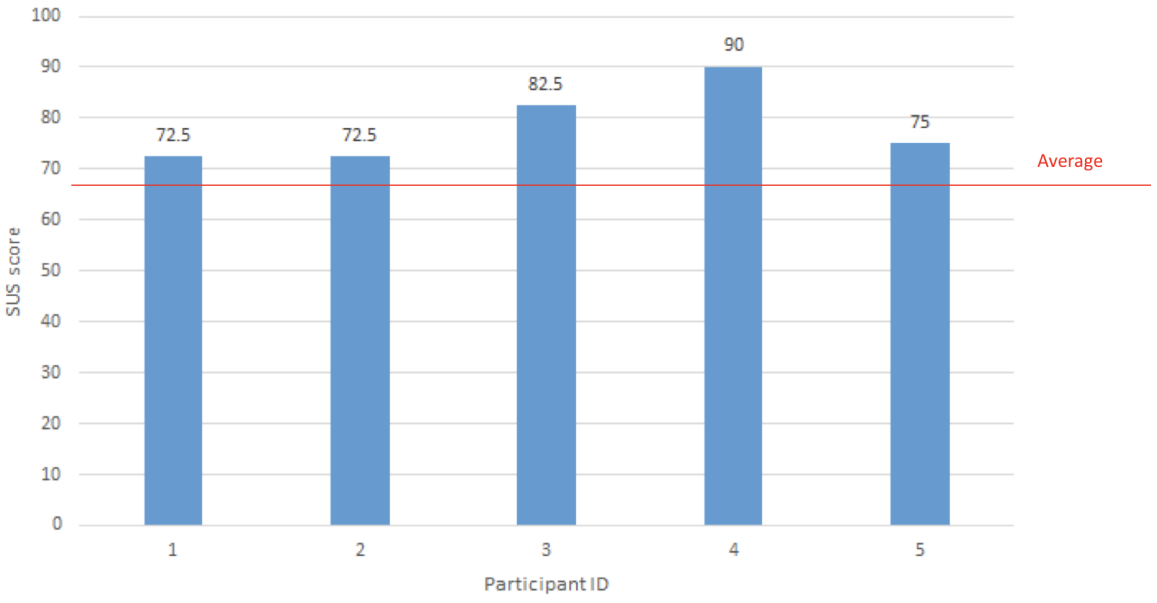

FIGURE 1.16: Summary of SUS results per participant.

The SUS average scores per question are depicted in Figure **??**. 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.

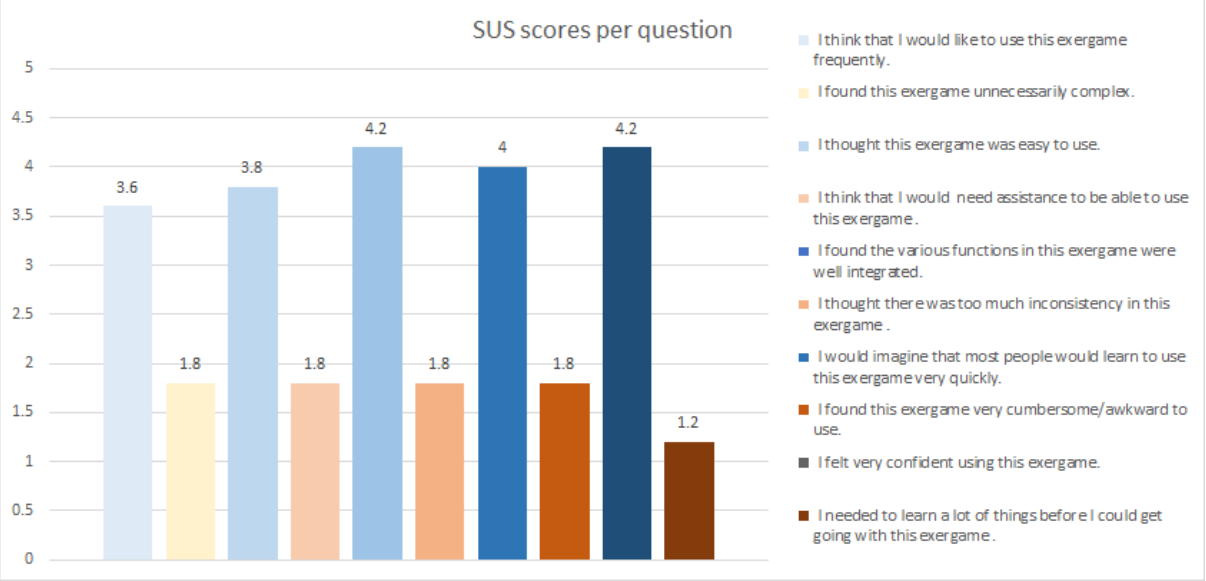

FIGURE 1.17: Summary of average SUS results for each question.

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.

1.2.8 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 **??** summarizes the PES results per question for each dimension discussed [2].

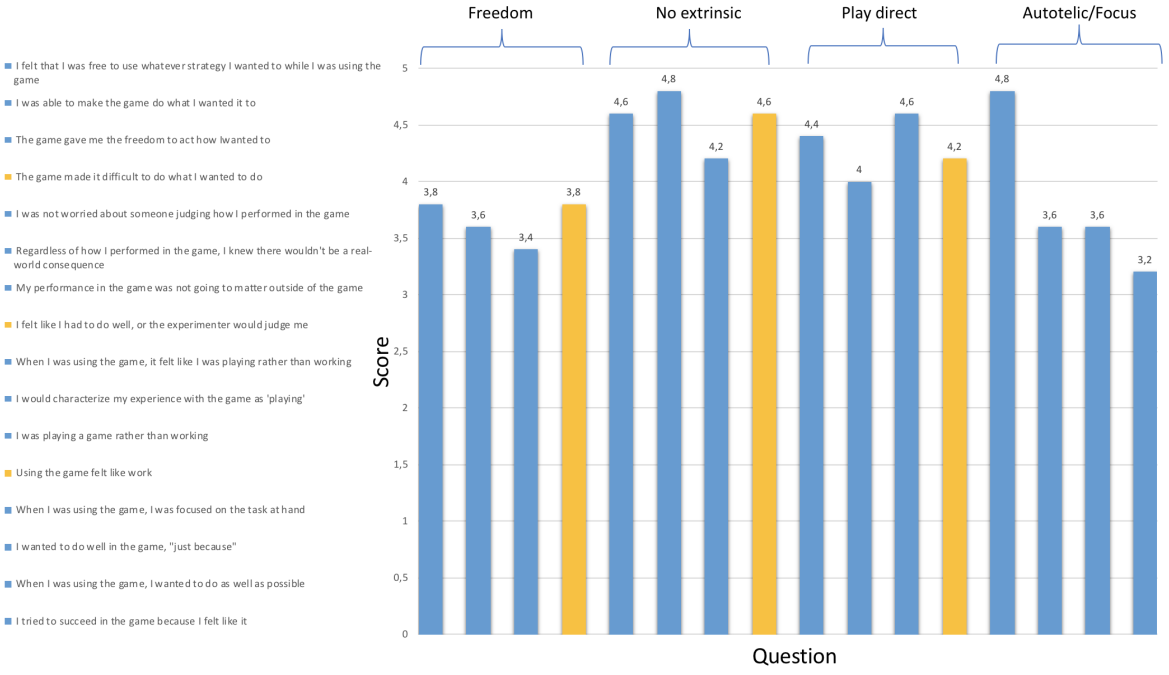

FIGURE 1.18: Summary of average PES scores per question.

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 **??**.

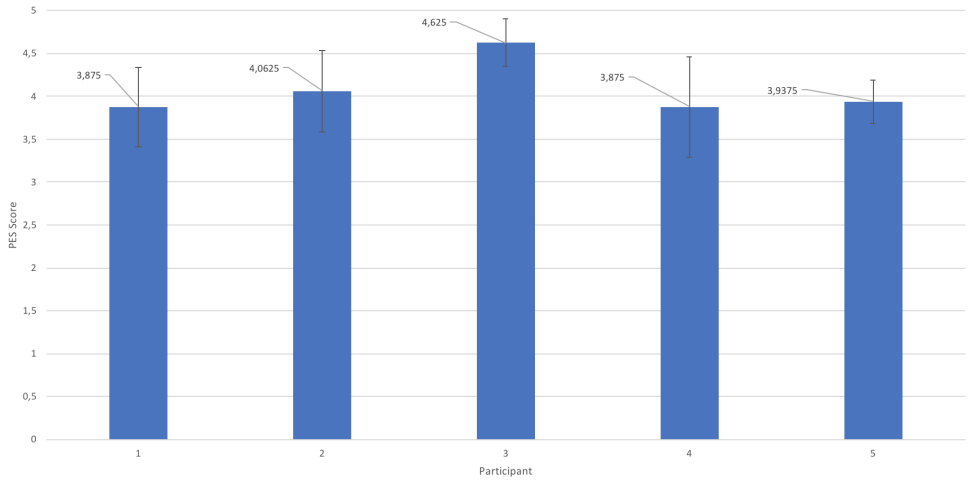

FIGURE 1.19: Summary of average PES score per participant.

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.

1.2.9 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 **??** depicts the obtained results.

FIGURE 1.20: 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*.

1.2.10 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.

1.2.10.1 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 **??**.

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 1.21: Post study questionnaire scores for the experiment group.

Based on the scores presented in Figure **??**, 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.*"

1.2.10.2 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 **??**.

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 1.22: Post study questionnaire scores for the control group.

From Figure **??** 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 **??** depicts the compared average scores with standard errors for the some of the statements discussed.

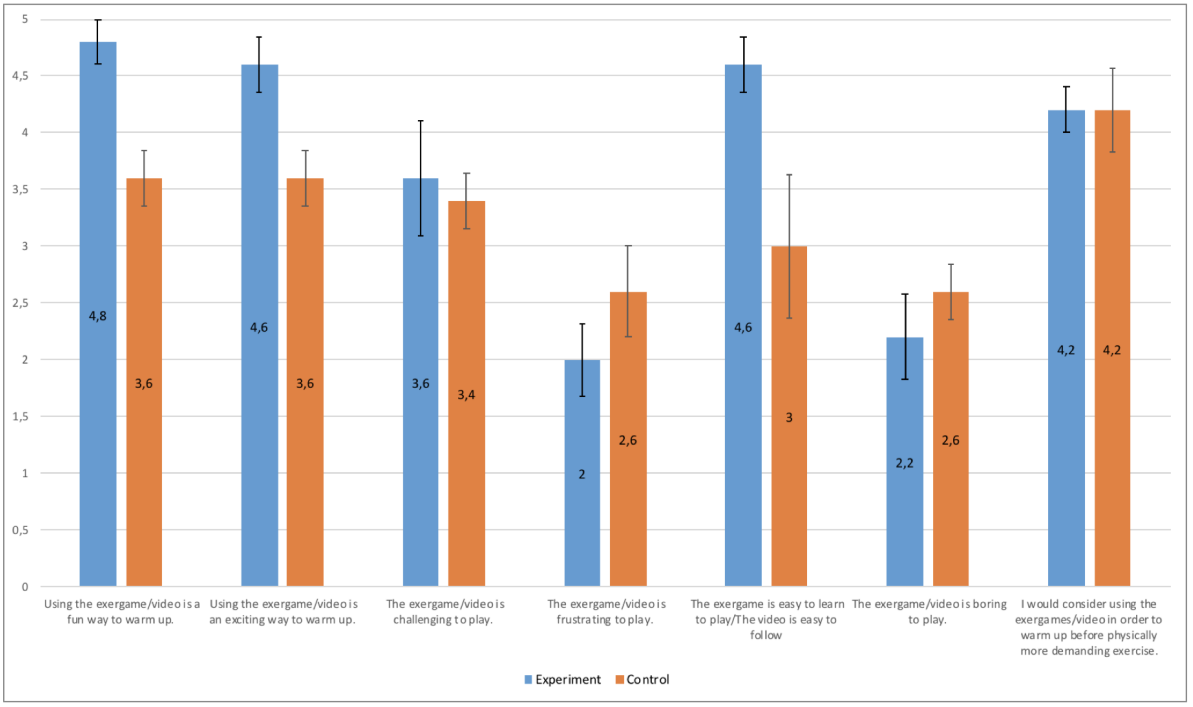

FIGURE 1.23: Average scores of the post study questionnaire for each condition.

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.

1.3 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.

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