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Designing a Casual Exergame for Moderate and Vigorous physical activity Using Squat-Based Motion and Skeletal Tracking

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Abstract

This thesis investigates how a casual exergame can be designed to promote moderate- to vigorous-intensity physical activity. A prototype exergame was developed using the Godot engine and MediaPipe for realtime body tracking. The game was evaluated through different approaches involving the Borg Rating of Perceived Exertion, participant questionnaires, and observational notes. Results indicate that while the game was engaging and well received with high levels of reported enjoyment and focus it generally failed to promote moderate or vigorous intensity exertion. Factors such as user unfamiliarity with controls, suboptimal movement mechanics, and specific game elements might have contributed to low exertion levels. Conversely, gate obstacles, which encouraged frequent squatting, demonstrated greater potential to increase physical activity. The evaluation also revealed technical and methodological limitations, such as the testing environment and lack of objective measures like heart rate monitoring. The study concludes that effective exergame design should prioritize continuous full-body movements, early-stage playtesting, and objective performance metrics.

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Introduction

In today's world, many people lead sedentary lifestyles, which contributes to various health problems such as obesity, heart disease, and mental health issues [3]. At the same time, digital entertainment, particularly video games, has become a major part of people's daily lives. This creates a unique opportunity to combine the fun of gaming with physical exercise. This idea, known as exergaming, involves using games to encourage players to move and be active. However, while many exergames focus on light or low-intensity activity, there is a need for games that can engage users in more intense exercise, like moderate- and vigorous-intensity physical activity. This thesis will explore how creating a social, casual exergame can motivate players to engage in these higher levels of physical activity while ensuring that the game remains enjoyable and accessible.

1.1 Background

Exergaming has shown promise as a tool to get people to exercise, especially for those who may not enjoy traditional fitness activities. A study from 2023 showed that playing exergames can improve certain aspects of young adults' quality of life, particularly in areas such as physical functioning, role-physical (role limitations due to physical health), general health, and social functioning [4]. Many exergames use motion-tracking technology, like in games such as Just Dance or Ring Fit Adventure, to get players moving. However, most of these games focus on light-intensity activity, which may not be enough to help people meet recommended physical activity guidelines. One approach to increase physical activity in daily life is to develop short casual exergames for quick play sessions. By focusing on microbreaks, casual exergame has the potential to make physical activity more achievable for individuals with busy schedules. Supporting this idea, a study made by Irene Drizi found that incorporating active breaks into the workday is beneficial for both standing and sedentary occupations. The study concluded that short breaks of 3 to 5 minutes every 30 minutes, or slightly longer breaks of 10 to 15 minutes every 40 to 60 minutes, effectively reduced the negative effects of prolonged sitting or standing[5]. To further support this idea, a research from 2023 explored different strategies to avoid sedentary behavior using casual exergames to promote active breaks. In a 45-week user study with office employees, reward-based gamification elements were introduced for an 11-week period to get their impact on break-taking behavior. The findings indicated that participants had a positive experience using the application and that the number of active breaks was higher during the gamified period compared to both the pre- and post-gamification period [6].

1.2 Approach

At Linköping University, many talented students and dedicated teachers are actively engaged in developing innovative exergames that combine exercise with engaging gameplay. It is within this environment that a 2D moon landing exergame will be designed. More specifically the game made for this study is made to be a part of *Liopep*, a software containing a collection of exergames aimed at creating healthier workplaces. Liopep's primary goal is to break up sedentary work with short, active breaks where employees engage in 2-3 minute-long exergame sessions. All games developed for Liopep adhere to specific constraints, including consistent fonts, a uniform UI layout, and development within the Godot game engine.

1.3 Aim

The aim of this thesis is to design and develop a casual exergame that encourages moderate- and vigorous-intensity physical activity. The game will combine enjoyable gameplay with elements to motivate users to engage in exercise that is not only fun but also beneficial for their health.

1.3.1 Research Questions

1. How can a casual exergame be designed to promote moderate- and vigorous-intensity physical activity?

1.4 Limitations

This research primarily focuses on individuals aged 18–45, which may limit the generalizability of our findings to other age groups, such as adolescents, older adults, or children. The study population is composed mainly of university students. This sampling limitation may impact the applicability of our findings to non-student populations or individuals outside academic settings.

Theory

This section draws on several interrelated fields, explaining the theory of the thesis.

2.1 Exergaming

Exergaming, a term derived from the fusion of "exercise" and "gaming," refers to the integration of physical activity with video gaming to encourage movement and exertion beyond sedentary levels. Unlike traditional gaming, which often involves minimal physical effort, exergames require players to perform physical movements as a core component of gameplay. These movements can range from simple gestures to more demanding activities that promote strength, balance, and flexibility[7]. According to Yang and Oh[7], exergames are designed to engage players in various forms of exercise while maintaining an enjoyable and interactive gaming experience. They often use motion-sensing technologies, such as Kinect, Wii Fit, or VR systems, to track players' body movements and translate them into in-game actions. This combination provides entertainment and measurable physical benefits by encouraging moderate- to vigorous-intensity physical activity.

2.2 Causal games

According to the International Game Developers Association (IGDA) [8], casual games are designed to be easily accessible and appealing to a broad demographic, regardless of age or gender. These games are characterized by their simplicity, offering straightforward gameplay with minimal controls, making them easy for players to pick up quickly. Play sessions are typically short, often lasting between 5 and 20 minutes. Casual games are also designed to run on basic hardware, avoiding the need for specialized equipment and maintaining low system requirements. The primary goal is to provide entertainment, relaxation, and a way to pass the time, emphasizing forgiving gameplay rather than punishing mechanics.

2.3 Related Work

2.3.1 Design Principles for Exergames

Previous studies have explored key design considerations for creating social casual exergames that effectively promote physical activity. [9] Emphasized the importance of integrating ambiguity in movements within game mechanics, allowing players to engage freely and creatively without the stress of precise control. This ambiguity in controls enhanced enjoyment and encourage greater physical exertion. Similarly, balancing cognitive complexity by ensuring game mechanics are clear yet varied prevents players from feeling overwhelmed while maintaining their interest and engagement [9]. The same studie also showed that the pace of gameplay also plays a significant role. Faster-paced games can distract players from the effort of physical exertion, keeping them more engaged and motivated. Providing feedback on player movements further enhances enjoyment by acknowledging their efforts and encouraging them to push themselves. Incorporating variety in game mechanics, such as scoring systems that reward movement or timing, has been shown to increase activity levels and sustain motivation.

2.3.2 Comparing Seated vs. Standing Casual Exergamess

Izabella, Aseel, Erik and Helena [10] found that casual exergames, with a short duration (2 minutes), provide an increased positive effective experience. The results showed a significant increase in positive affect for both seated and standing gameplay, with a large effect size for seated ($d = 0.87$) and a medium-to-large effect for standing ($d = 0.71$). The effect size (Cohen's d) represents the strength of the observed difference, where 0.2 is considered small, 0.5 medium, and 0.8 large, indicating that seated gameplay had a significant impact on positive affect compared to standing. However, no significant differences were found between the two positions in terms of positive affect, perceived exertion, enjoyment, or performance. Additionally, negative affect remained very low both before and after gameplay, making further analysis difficult. These findings suggest that short-duration casual exergames can effectively enhance mood, regardless of whether players are seated or standing. Measures of exertion, enjoyment, and performance also showed no significant differences, showing that both formats provide comparable engagement and benefits [10].

2.3.3 Validated Tools for Measuring Gamification

[11] Highlights the importance of using validated tools to measure the effectiveness of gamification in digital health interventions. These tools make use of user experience, usability, and player engagement to ensure that gamified elements improve motivation and interaction. The study showed that the User Experience Questionnaire (UEQ) was effective in evaluating factors such as attractiveness, efficiency, and motivation, showing insights into user perception. Additionally, the System Usability Scale (SUS) is still one of the most widely used instruments for assessing the overall usability in gamified systems. To measure the emotional and functional impact of gamification, the Player Experience Inventory (PXI) and Gameful Experience Scale (GES) offers valuable insights. PXI examines how game design choices influence immediate user experiences and emotional responses, while GES evaluates key aspects like enjoyment, absorption, and creative thinking. These tools provide a comprehensive framework for assessing gamification's role in enhancing the user experience [11].

2.3.4 Impact of Reactive vs. Strategic Mechanics in Exergames

Erik, Aseel, Erik B and Fabio[12] made a study in 2017 with 35 participants, investigated the impact of two different game mechanics, one reactive and one strategic within a casual motion-based game. Results from this study showed no significant differences in player experience, performance, or movement between the two mechanics. A key factor in players' preference for a game mechanic was the perceived cognitive demand it required, where a less cognitive game mechanics was preferred [12].

2.3.5 Balloon Pump

Balloon Pump[13] is an exergame developed in 2023 for *Liopep* using MediaPipe. The authors evaluated the game at a game and cosplay festival with 60 participants, where aspects such as perceived exertion, control, immersion, and overall experience were measured. Performance and the number of movements were also recorded by the authors. The results indicated that the game was seen as controllable, provided sufficient exertion, and was enjoyable. However, the immersive experience was rated as low, with participants suggesting improvements like the addition of more incentives and varied gameplay to improve engagement [13].

2.3.6 The Role of Points in Gamified Learning Systems

A study from 2022 [14] explored the impact of individual game elements in a gamified Learning Management System (LMS) in higher education, focusing on the role of points as a game element. The study found that students' perceptions of points were positively associated with the enjoyable quality of the LMS, suggesting that the perceived value and motivation of points were important in enhancing the user experience. Furthermore, the study highlighted the novelty effect, noting a significant decrease in students' perception of points over time. Initially, points were perceived as motivating and valuable by the students, but these perceptions diminished by the eighth week of the course. This phenomenon suggests that gamified elements, such as points, may experience an initial boost in engagement, followed by a decline as novelty wears off. The study concluded that when designing point-based systems, considerations of both the value and motivational aspects of the points, and how novelty effects can be mitigated, are essential for maintaining user engagement over time [14].

2.3.7 The Impact of Goal Setting in Exergames

A previous study [15] investigates how goal setting in casual exergames affects players performance, exertion, and enjoyment. The researchers wanted to see if setting specific goals during gameplay could make the game more effective in terms of physical effort (exertion) and more enjoyable. The study shows that setting goals in casual exergames can help increase players' physical effort and enjoyment, but it may not always make them perform better in the game [15].

2.3.8 Impact of Upper vs. Full Body Movement Controllers

A study from 2023 [16] investigated how the type of body movement used to control casual exergames impacts players' experience. The research compared two groups of players: one used upper-body movement controllers, while the other used full-body movement controllers to play the same casual exergame. The study suggests that while full-body movement controllers might not necessarily lead to a better gaming experience in terms of immersion or exertion, upper-body controllers can still provide adequate control and should not be overlooked when designing casual exergames [16].

2.3.9 Squats as a High-Exertion Exercise

Jung-Yong and Imran [17] investigated the levels of perceived exertion and muscle fatigue associated with squat exercises. This study highlights the significant role of squats in inducing perceived exertion and muscle fatigue, showing their status as a demanding physical exercise that engages multiple muscle groups. Key findings from the study revealed that the lower extremities, particularly the rectus femoris, experience the highest levels of fatigue during squat exercises, demonstrating the substantial muscular engagement involved. The use of electromyography (EMG) analysis further supports this by showing the activation of major muscles during the movement [17].

Methodology

This chapter outlines the methods and tools employed to develop and evaluate the exergame designed for this study.

3.1 Godot

The Godot Engine is an open-source game development platform released under the permissive MIT license. This licensing model ensures that developers incur no costs, fees, or royalties on revenue generated from their games, a significant advantage that sets it apart from many other game engines, which often impose such financial obligations. Godot uses its own scripting language, GDScript, which is designed to be lightweight and easy to learn, especially for game development. However, it also supports other programming languages, such as C#, C++, and VisualScript, offering flexibility to developers with varying preferences and expertise [18]. For this project, GDScript is used.

3.2 Measurements

To evaluate the effectiveness of the exergame in promoting physical activity, a series of user tests were conducted. During these tests, participants engaged with the game while various data points were collected to assess both their physical exertion and overall gameplay experience. To measure each test-user's physical activity, a subjective measure was used. For this subjective measurement, the Borg RPE was used, discussed in section 3.2.1.

3.2.1 Borg Rating of Perceived Exertion

Borg Rating of Perceived Exertion, also called Borg RPE, is an outcome measurement scale used to perceive the intensity of a certain workout, without the need for physiological parameters such as O2 uptake, heart rate and lactate levels [2]. The primary focus of this measurement is to rate exertion, breathlessness and fatigue during physical activity. The scale spans from 6 (no exertion) to 20 (maximal exertion), with scores of 11–12 corresponding to light activity, 13–14 to moderate intensity, and 15–16 to vigorous exertion, see Table 3.1.

RPE Score	Description
6	No exertion
7-8	Very light
9-10	Light
11-12	Moderate
13-14	Somewhat hard
15-16	Hard (vigorous)
17-18	Very hard
19	Extremely hard
20	Maximal exertion

Table 3.1: Borg Rating of Perceived Exertion (RPE) Scale. [2]

3.2.2 Questionnaire

To further investigate the user tests, a questionnaire was designed to gather qualitative and quantitative data on participants' experiences with the exergame, see Appendix A. The purpose of this questionnaire was twofold: first, to evaluate the usability, engagement, and emotional involvement with the game; and second, to gain insights into potential design factors that contribute to eliciting moderate- to vigorous-intensity physical activity. The questionnaire can be found in chapter: A.

The questionnaire consisted of nine statements rated on a five-point Likert scale, ranging from "Strongly Disagree" to "Strongly Agree." These statements were grouped into two thematic categories: immersion (questions 1, 3, 5, 6, and 8) and control (questions 2, 4, 7, and 9). This division aimed to distinguish how the game was perceived both in terms of engagement and interactivity. The responses provide a structured view of how players experienced the game's interface, responsiveness, and emotional draw.

3.2.3 Observational Notes

In addition to the self-reported data, observational notes were collected during each testing session by the researcher to document participant behavior and physical responses that may not have been captured through questionnaires. The purpose of these observations was to qualitatively assess player behavior, body movement, engagement, and any moments of confusion or hesitation while interacting with the game.

3.3 MediaPipe

MediaPipe [19] is an open-source framework developed by Google that offers tools for real-time, cross-platform machine learning solutions, including pose estimation and object detection. MediaPipe uses a deep learning-based model to detect 32 key points on the human body, such as joints and extremities, from a single RGB camera feed. This is how it works [19]:

1. **Region of interest Detection:** The first step involves identifying the human body within the video frame using object detection algorithms. This applies a bounding box-based detection to localize the subject, narrowing down the area to be analyzed. This step reduces computational complexity by focusing only on the relevant portion of the image.

2. **Landmark Detection:** Once the region of interest has been calculated, MediaPipe uses pose estimation algorithms based on deep neurual networks to predict 32 key body landmarks, see figure 3.1.

3. **Pose Refinement and Temporal Smoothing:** To improve tracking accuracy, MediaPipe applies *Keypoint Refinement*, which adjusts the detected landmarks for finer accuracy by using spatial relationships between points, such as limb lengths and joint positions. *Temporal Smoothing* minimizes jitter or abrupt changes in landmark positions, ensuring a smooth tracking experience even during fast movements.

4. **Cross-Platform Optimization:** The pose estimation pipeline is designed to work efficiently on various platforms, including desktops, mobile devices, and web browsers. MediaPipe leverages lightweight neural networks and hardware acceleration (e.g., GPU/TPU) to ensure real-time processing even on low-power devices.

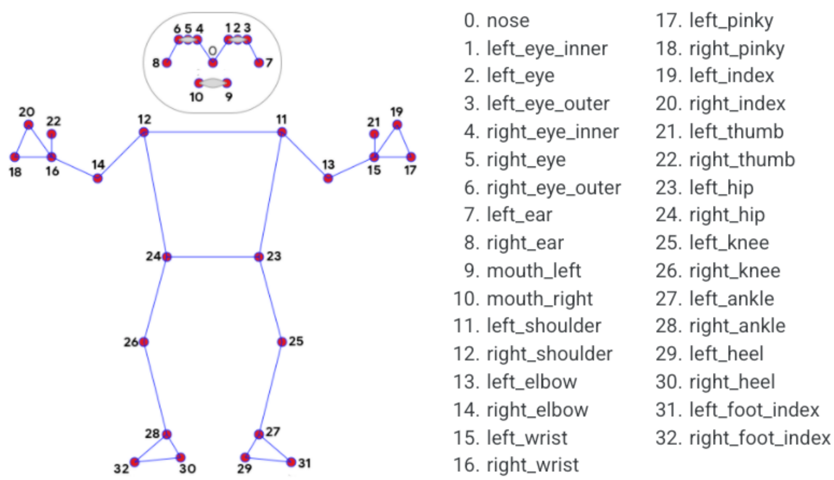

Figure 3.1: 32 LandMarks [1]

Result

This chapter presents the outcomes of the exergame development and its subsequent evaluation. It is divided into two main sections: the game design process and the evaluation of player experience and physical engagement.

4.1 Game Design

As mentioned in 2.3, alot of features is to be taken in consideration when making an exergame according to previous studies. In this section the reasoning and method for these features are described aswell as the overall game design.

4.1.1 Game Overview

The final game features a 2D air balloon that ascends vertically, with the player's main objective being to controll this balloon while collecting as many coins as possible within a set time limit. Coins are scattered randomly, but players must navigate around obstacles by using different body movements. The balloon's movement is entirely controlled through the user's physical actions. Figure 4.1 shows and overview of what the game looks like at the start.

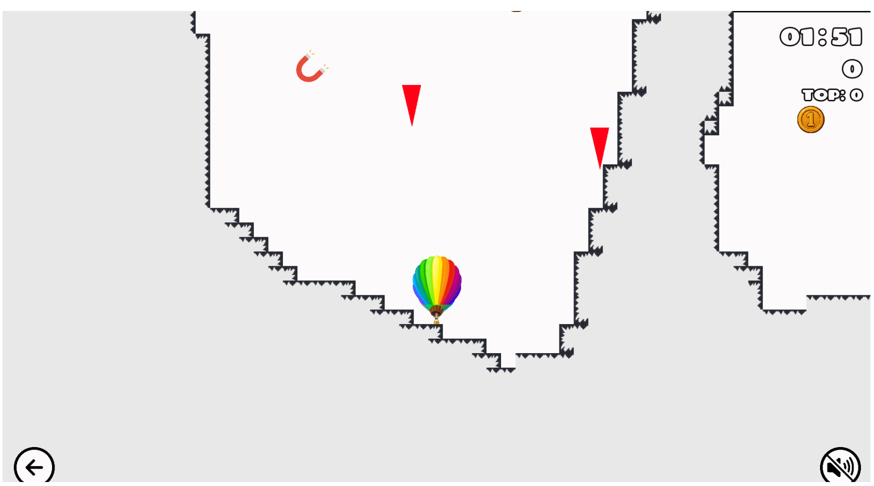

Figure 4.1: Game Overview

4.1.2 Movement Mechanics

To implement the movement mechanics into the game MediaPipe was used, discussed in 3.3 A lot of focus has been placed on squat movements due to the study mentioned in 2.3.9.

Vertical Movement

The vertical movement is first of all affected by a downforce that is gravity. To move against this force, the player must squat. When the player squats, the air balloon gets an initial force, based on the current squat strength. Figure 4.2 illustrates the key steps involved in executing a squat.

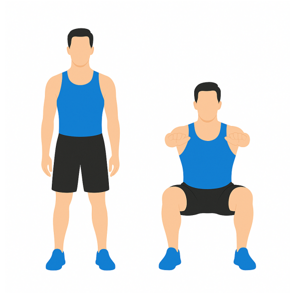

Figure 4.2: Squat Movement

To prevent the game from requiring the player to squat continuously, a heat system modeled after a real air balloon was implemented. Whenever the player squats, heat is generated and stored in the balloon. The amount of heat determines the balloon's automatic lift force, allowing it to ascend independently once a certain heat threshold is reached. There are 3 different heat thresholds the balloon can reach, green, orange and red, the UI for these different threshold can be shown in figure 4.3.

Figure 4.3: UI for 3 different heat variations

To give players more control over vertical movement, a downward force system releasing heat was implemented. This mechanic allows players to actively reduce heat levels in the balloon while also initiating a controlled descent. To activate this feature, the player must raise their hands above their nose, triggering the system to release heat and apply a downward force. The pose detection system was calibrated to recognize this gesture by ensuring that the player's elbows are positioned above their nose. Figure 4.4 illustrates the key steps involved in initiating a controlled descent.

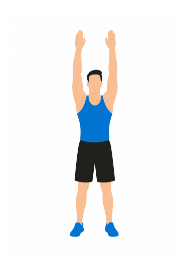

Figure 4.4: Vertical Downward Movement

Horizontal Movement

In addition to vertical movement, horizontal movement allows the player to navigate the game environment sideways. The balloon's horizontal motion is controlled by shifting the player's arms to the left or right. Simply put, raising and lowering the right arm causes the balloon to turn left. The faster the arm movement, the quicker the balloon turns, effectively integrating moderate- to vigorous-intensity physical activity. To track the arm movement, the elbow locations where used. Figure 4.5 illustrates the key steps involved in moving the ballon horizontal.

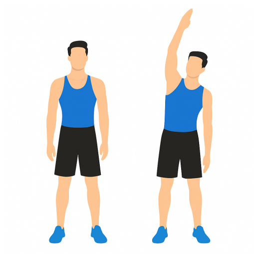

Figure 4.5: Horizontal Movement

4.1.3 Score System

To score points in the game, the player must collect coins, which come in two types: big coins and small coins. Big coins are worth more points than small coins and are usually harder to reach in the game. However, collecting coins is not the only aspect of the score system, players can also lose coins under other circumstances.

When a player collides with a wall, they lose a small number of coins as a penalty for the misstep. Similarly, getting hit by a projectile results in a more substantial coin loss. This mechanic is not only meant to introduce challenge but also to follow the design principles of effective exergames.

4.1.4 Map Implementation

The map in the game is generated using a simple and efficient method based on a 2D image. Specifically, a grayscale image where black pixels represent walls, and white pixels indicate traversable space. During initialization, a tilemap system reads the image and automatically places tiles wherever the pixel color is black.

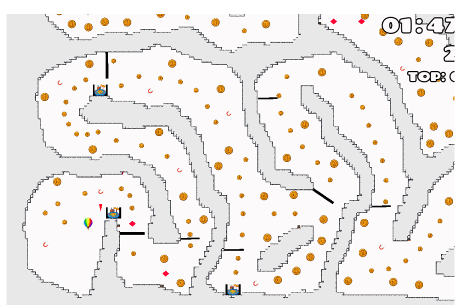

Figure 4.6: Final Map Layout

4.1.5 Additional Game Elements

To further enrich the gameplay experience and promote more dynamic movement, several additional game elements where implemented. These features serve to increase variation and support higher levels of engagement and physical exertion, all of which are emphasized as important design principles in the context of exergames 2.3.1.

One such element that has been implemented is the magnet power-up. When the player collects this item, it activates a temporary magnetic field around the balloon character, pulling in nearby coins automatically. See Figure 4.7

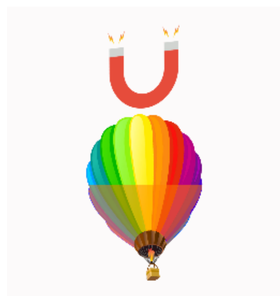

Figure 4.7: Magnet Power-up

In addition to the magnet, a mechanic called the *landing station* was implemented. When the player lands on or enters a designated landing station area, it triggers an in-game event such as opening a gate or moving an obstacle. This mechanic introduces basic environmental interaction and puzzle-like elements, allowing certain parts of the map to become accessible only after specific actions are taken. Figure 4.8 shows an in-game situation where a player must land on a landing station to move a black vertical pillar.

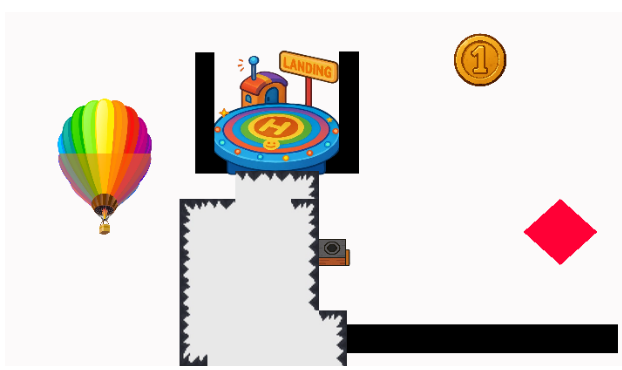

Figure 4.8: Landing Station

Another mechanic that was implemented is timed gates that open and close at regular intervals. These gates require the player to anticipate and time their movements in order to pass through successfully. This feature encourages bursts of physical effort and enhances cognitive engagement by introducing a reactive challenge. Figure 4.9 shows a black gate in-game.

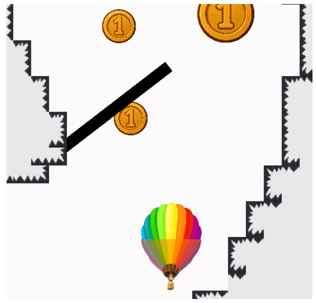

Figure 4.9: Gates

Another implemented element is the projectile shooter, see Figure 4.10, which fires large, slow-moving projectiles in a straight line. If hit, the player loses coins, introducing a light penalty and creating risk and reward dynamics.

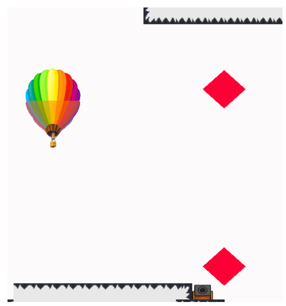

Figure 4.10: Projectile Shooter

Lastly, falling spike enemies were added, see Figure 4.11. These spikes spawn above the player and slowly descend in a vertical movement, forcing the player to stay alert and reposition themselves to avoid being struck. Like the projectile mechanic, being hit by a spike results in a coin penalty. This mechanic introduces a vertical threat, requiring players to remain mobile.

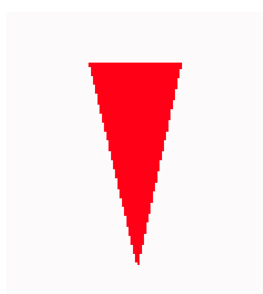

Figure 4.11: Falling Spike

4.2 Evaluation

To evaluate the effectiveness and user experience of the exergame, a total of eight participants were recruited for playtesting, with an even gender distribution (four women and four men) and an age range between 24 and 31 years. Of all participants, 75% reported having played the game several times or for an extended period, while the remaining 25% indicated they had only played on some occasions.This group provided both subjective physical activity data and responses through the questionnaire, forming the basis for the following analysis. Before testing began, each participant was given a brief introduction explaining how to move within the game, what the main goal was, and what actions they should focus on. To ensure clarity, a short demonstration was provided by the researcher, who showed an example of gameplay to familiarize participants with the mechanics. All tests were conducted on a laptop with a relatively small screen, which may have influenced the level of visual immersion and physical movement during gameplay.

4.2.1 Borg Rating of Perceived Exertion

Table 4.1 presents the distribution of participants' self-reported exertion levels using the Borg Rating of Perceived Exertion (RPE) scale, collected immediately after gameplay to assess the intensity of physical activity experienced during the exergame session. The table includes each RPE level along with a brief description of the perceived exertion it represents. The final column shows the percentage of participants who selected each RPE value, indicating how many users reported experiencing that specific level of physical effort during the test.

Table 4.1: Borg Rating of Perceived Exertion Reported by Participants

RPE	Description	Percentage
6	No exertion at all	14.3%
7	Extremely light	14.3%
8		0.0%
9	Very light	14.3%
10		0.0%
11	Light	14.3%
12		0.0%
13	Somewhat hard (Moderate)	28.6%
14		0.0%
15	Hard (Vigorous)	14.3%
16		0.0%
17	Very hard	0.0%
10		0.0%
19	Extremely hard	0.0%
20	Maximal exertion	0.0%

Based on the Borg RPE responses collected from participants, the mean value was 10.57 with a standard deviation of 3.11. These results are derived from the data presented in Table 4.1.

4.2.2 Questionnaire

Table 4.2 presents the results of the questionnaire, which assessed participants' perceptions of the exergame experience. Each row represents a specific question, while each column shows the percentage of participants who selected one of the five likert scale options. The response categories are as follows:

- **SD (Strongly Disagree)** – the participant completely disagreed with the statement

- **D (Disagree)** – the participant somewhat disagreed
- **N (Neutral)** – the participant neither agreed nor disagreed
- **A (Agree)** – the participant somewhat agreed
- **SA (Strongly Agree)** – the participant completely agreed with the statement

The questionnaire was completed by a total of seven participants. Table 4.3 shows the mean-

Table 4.2: Participant Responses to Questionnaire Items

#	Question	SD	D	N	A	SA
1	I felt like I lost track of time while playing	0.0%	0.0%	28.6%	57.1%	14.3%
2	I felt that it was difficult to understand how the game works	28.6%	42.9%	28.6%	0.0%	0.0%
3	I was focused on the game	0.0%	0.0%	0.0%	14.3%	85.7%
4	I felt it was easy to familiarize myself with the game controls	0.0%	0.0%	28.6%	57.1%	14.3%
5	I felt emotionally attached to the game	0.0%	14.3%	42.9%	42.9%	0.0%
6	I felt a strong sense of being in the game world	0.0%	28.6%	28.6%	14.3%	28.6%
7	I felt that the game reacted quickly to my actions	0.0%	0.0%	42.9%	57.1%	0.0%
8	I did not feel like I wanted to keep playing	57.1%	42.9%	0.0%	0.0%	0.0%
9	I felt in control of the game	0.0%	28.6%	0.0%	42.9%	28.6%

value and standard deviation (SD) results from Table 4.2.

Immersion: The total mean score for the immersion category (Questions 1, 3, 5, 6, and 8) was 4.00, indicating a generally strong sense of engagement and presence.

Control: The total mean score for the control category (Questions 2, 4, 7, and 9) was 3.54, reflecting an overall positive but slightly more varied experience of control during gameplay.

Table 4.3: Mean and Standard Deviation of Questionnaire Items

Q#	Mean	SD	Notes
1	3.86	0.64	Generally high immersion
2	3.00	0.82	Neutral-positive after reverse coding
3	4.86	0.35	Very high focus and agreement
4	3.86	0.64	Mostly positive responses
5	3.29	0.70	Mixed responses, leaning positive
6	3.43	1.13	High variability in responses
7	3.57	0.53	Generally positive control feedback
8	4.57	0.53	Very strong desire to continue playing
9	3.71	1.11	Broad spread, but overall positive

Additional information from users

At the end of the questionnaire, participants were given the opportunity to provide open-ended feedback about their gameplay experience. Three participants submitted additional comments. These responses are presented below in Table 4.4.

Table 4.4: Open-ended User Feedback

Participant	Comment
1	I felt in control most part but I had difficulties steering the balloon by moving my arms. This however made me put in more effort.
2	I felt that I was starting to understand the controls at the end of the game, I think that the game would be more enjoyable the second time.
3	Simpler and more distinct visuals (especially for the buttons) would be appreciated.

4.2.3 Observational Notes

In addition to questionnaire responses, observational notes were collected during each gameplay session to capture real-time behaviors, body movements, and user reactions. My most common observations where the following:

- Some participants appeared less engaged due to initial uncertainty about how to control movement horizontal and downwards. This led to a pause of uncertainty a couple of seconds for many users.
- A few participants showed a desire to play the game again after their session.
- All participants performed a very few amount of squats during each gameplay.
- Each participant show very little hesitation during movement upwards, in other words they directly performed squats without hesitation when they needed the balloon to move upwards.
- Participants attempted to move left or right by moving the corresponding arm; however, this was opposite to how horizontal movement was actually implemented.
- Many participants paused for extended periods at the shooter obstacles, discussed in 4.1.5, trying to cross without being hit.
- Gates, discussed in 4.1.5, forced all participants to engage in a fast squat movement to move past it.
- The movement mechanics behaved somewhat unexpectedly for two participants, particularly with horizontal movement, where they struggled to steer sideways

Discussion

The aim of this thesis was to design and evaluate a casual exergame that encourages moderate- to vigorous-intensity physical activity.

5.1 Results

5.1.1 Evaluation

Overall, the results indicate that the exergame encouraged a relatively low level of physical exertion. As shown in Table 4.1, the mean reported exertion was 10.57, with a standard deviation of 3.11. This average corresponds to a perceived intensity between “Light” and “Somewhat hard (Moderate)” on the Borg RPE scale, suggesting that most participants experienced the game as moderately physically demanding.

The relatively high standard deviation indicates a wide spread in responses, implying that some participants experienced the game as very light, while others perceived it as moderately intense. According to observational notes (Section 4.2.3), several participants spent a significant portion of the session learning the movement controls, which may have influenced both the consistency and intensity of physical engagement.

Additionally, the number of squats observed per run was generally low. Since squatting was the movement that participants hesitated the least to perform, this likely contributed to the moderate exertion levels. Decreasing the initial lift force of squats could increase the frequency of movement, discussed in Section 4.1.2, potentially raising the overall exertion level. Alternatively, adjusting the automatic lifting force determined by the accumulated heat from repeated squats could also influence movement frequency and exertion, as discussed in Section 4.1.2. Therefore, it is important to design a system that can be easily modified after testing and that offers multiple adjustable parameters, allowing fine-tuning of exertion rates to better match desired outcomes.

In terms of subjective experience, the questionnaire results reflect strong engagement. The average immersion score was 4.00, and the control score was 3.54, both on a five-point scale. These values indicate that participants generally found the game engaging and reasonably easy to control, despite some variation.

The results suggest that the exergame exhibits several key traits of a casual game, as defined in Section 2.2. Participants reported high immersion (M = 4.00) and moderate control (M = 3.54), suggesting that the game was generally accessible and engaging, even in short sessions. The use of simple, webcam-based input and short play durations aligns with the casual genre’s emphasis on low system requirements, minimal controls, and ease of access [8].

However, both open-ended feedback (Table 4.4) and observational notes (Section 4.2.3) indicate that some participants struggled with mastering the controls—particularly for horizontal and downward movement. For example, one participant noted only beginning to understand the control scheme near the end of the session, while others experienced confusion due to mismatches between expected and actual control behavior. This initial learning curve suggests that, while the game meets many casual design goals, further refinement of the control system and visual clarity could improve its accessibility and better support the casual experience. In this context, minimizing the number of controls in a casual exergame appears beneficial and is supported by these findings. Furthermore, conducting additional testing with the same participants could have been a viable solution to assess whether familiarity over time would reduce confusion and improve interaction with the exergame.

5.1.2 Game Design

Movement Mechanics

The selection of movement mechanics in this game was made with a strong focus on maintaining player engagement while encouraging physical activity. A deliberate emphasis was placed on squat mechanics, supported by the research discussed in 2.3.9, due to their proven effectiveness in inducing moderate- to vigorous-intensity physical exertion.

Horizontal and downward movement gestures were also introduced to provide a broader range of control and avoid overly repetitive gameplay. These mechanics were selected specifically to address concerns raised in previous exergame studies, such as Balloon Pump, where participants rated immersion poorly and requested more diverse interactions to sustain engagement.

However, it's important to acknowledge that while these movement mechanics were designed to enhance engagement, my observational notes (see Section 4.2.3) and user feedback (Table 4.4) indicate that several participants spent a significant portion of the session trying to understand and master the controls. This suggests that while varied and physically engaging, the mechanics may have been too complex initially, potentially limiting immediate immersion and ease of use for some players. This level of complexity does not align well with the core principles of casual exergames (Section 2.2), which emphasize simplicity, minimal controls, and ease of access to ensure a quick and intuitive onboarding experience for a wide audience. Minimizing the amount of controls to just one or two core actions would likely have been more appropriate for supporting these casual design goals and reducing the initial learning curve.

Moreover, the open-ended feedback (Table 4.4) reinforces this issue. For instance, Participant 2 noted that they only began to understand the controls near the end of the game, indicating a delayed sense of mastery. Participant 1 acknowledged control difficulty but also suggested it encouraged more physical effort highlighting a tradeoff between challenge and accessibility. Importantly, Participant 3 specifically requested simpler and more distinct visuals. This points to a critical area for improvement: the visual communication of movement effects. Clearer visual cues such as animations or on-screen indicators showing how each movement influences the balloon could have eased the learning curve and enhanced the intuitive feel of the control scheme.

Score System

The score system was designed to balance reward and challenge, encouraging full-body engagement through both coin collection and coin loss. Differentiating between small and large coins supports short-term goal setting, which is known to enhance motivation and exertion in exergames 2.3.7.

Penalties for hitting walls or projectiles introduce light consequences, encouraging players to stay alert without overwhelming them—reflecting the balance between clarity and cognitive load outlined in 2.3.1. This dynamic feedback system helps players feel their actions matter, which is essential for immersion.

However, as noted in Section 4.2.3, some players were frustrated by unexpected coin loss, suggesting clearer in-game feedback is needed. Also, the questionnaire lacked targeted questions about the score system, limiting insight into its perceived impact.

Even if certain penalties reduced exertion or caused confusion, they may still have added to the game's emotional engagement. Rather than removing such elements, adjustments—like fine-tuning values or improving clarity—could preserve their benefits while better supporting physical activity.

Map Implementation

The grayscale image-based map system was chosen for its simplicity, flexibility, and impact on gameplay. It allows rapid prototyping and easy level editing without code changes—an important feature for exergames where map layout directly affects movement patterns and physical exertion. This method also supports the balance between variation and clarity, as emphasized in 2.3.1. Designers can create diverse layouts with consistent logic, keeping gameplay engaging without overwhelming players. Whether the map layout had any influence on the observed results is difficult to determine at this stage and would require further testing. However, the ease with which the layout can be modified demonstrates that such testing could be conducted efficiently. This underscores the importance of creating adaptable systems when developing exergames, enabling iterative refinement and targeted experimentation without significant redevelopment effort.

Finally, this approach aligns with feedback from the Balloon Pump study 2.3.5, where participants requested more varied and dynamic environments. By enabling fast iteration and spatial diversity, this system helps meet those expectations and sustains long-term engagement.

Game Elements

The additional game elements were implemented to increase gameplay variation and sustain engagement, which are key principles in effective exergame design 2.3.1. As shown in the Balloon Pump study, a lack of variety can reduce immersion.In this case, the inclusion of varied game elements appears to have been successful, as evidenced by an immersion score of 4.00, indicating a positive player experience and suggesting that these additions effectively contributed to maintaining engagement.

The magnet power-up supports more fluid movement and introduces a positive feedback loop, aligning with research that shows ambiguity in control can enhance enjoyment and reduce frustration from precision-based tasks 2.3.1.

Landing stations contribute to implicit goal-setting and progression, encouraging players to engage in purposeful navigation. This reflects findings from 2.3.7, which emphasize the importance of short-term goals in increasing both exertion and enjoyment.

Timed gates introduce reactive and time-based challenges that promote bursts of physical effort, a design strategy shown to increase flow and perceived exertion 2.3.1. Timed gates were found to effectively promote bursts of physical effort and increased engagement. As observed during testing, these gates encouraged frequent squat movements, directly contributing to moderate- to vigorous-intensity physical activity. This aligns well with the principles of reactive challenge and perceived exertion 2.3.1. However, even if certain elements like the projectile shooter reduced physical effort, they might still have contributed significantly to player enjoyment and excitement. Removing such elements purely based on exertion outcomes could compromise overall engagement. To better evaluate this balance, future studies should include more targeted questionnaire items that assess the perceived fun and impact of each specific mechanic.

Projectile shooters and falling spikes introduce light penalties and risk, creating emotional engagement and heightening the perceived value of success, consistent with the role of consequence in motivating players 2.3.6. Projectile shooters led participants to slow down and act cautiously, as noted in observational notes (Section 4.2.3). This behavior reduced overall physical exertion and may contradict the primary goal of encouraging sustained activity. From this perspective, the shooter mechanic may not be optimal for promoting exertion-focused gameplay and may require revision or removal during future iterations.

Collectively, these elements help balance cognitive simplicity with gameplay depth, supporting sustained physical activity and motivation over time 2.3.1.

5.2 Method

The method for detecting body movements in combination with using godot, discussed in 3.3, has been shown to be very effective for exergames of this sort. During my work, I noticed that the camera could detect body parts with surprising accuracy. One noteworthy point is how easy it is to use a camera for everyday purposes, which makes the game accessible to a broader audience. However, question 4, 7 and 9 from table 4.2 shows somewhat of a mixed review of the movement accuracy. Most noticeable is that 28.6 percentage disagreed on that they felt in control of the game. This statement is further supported by the last observational note in Section 4.2.3. Even though 28.6 percentage is not a majority, it is still worth noting that some participants struggled with this. However, I would not attribute this issue to the use of MediaPipe, but rather to a flaw in the testing process, which i will discuss below.

The method used to evaluate the exergame has proven to be effective and reliable for assessing whether it can promote moderate- to vigorous-intensity physical activity. By combining Borg RPE, questionnaires, and observational notes, a substantial amount of valuable information could be gathered throughout the testing process. However, i believe it would have also been beneficial to include an objective measurement, such as a heart rate monitor. The reason for this is to also gather objective data, as subjective tests can sometimes be unreliable or influenced by personal bias. Another important point is that the testing process could have been improved. Firstly, the tests were conducted on a laptop with a small screen placed on a low table. This setup made it difficult for participants to see the screen clearly and also altered the camera angle significantly compared to the one used during the game's design. These factors likely influenced the results. Additionally, the small number of participants represents a significant limitation when investigating the findings, as it reduces the reliability and generalizability of the results.

Another valuable approach would have been to include a testing phase early in the game development process to identify and remove game elements or movements that reduce participant engagement or encourage inactivity.

Conclusion

6.1 Research Question

Designing a casual exergame to promote moderate- to vigorous-intensity physical activity requires a balance between accessibility, engagement, and exertion. A simple motion-recognition system is essential to support intuitive controls and align with casual game design principles. Minimizing the number of movement mechanics, focusing on core actions like squats, helps reduce the learning curve and improves accessibility.

Clear visual feedback is equally important, helping players understand how their movements affect gameplay and easing the onboarding process. Additionally, including reactive game elements such as timed gate obstacles can effectively increase physical intensity by encouraging quick, repeated movements. Varied game elements also play a key role in maintaining player immersion, as a lack of gameplay variety can reduce engagement over time.

Finally, building a flexible system with adjustable parameters allows for fine tuning and future iterations, making it easier to match exertion levels to design goals. Together, these elements create a foundation for exergames that are both engaging and physically effective.

6.2 Evaluation

An important insight from this study is the value of implementing an earlier evaluation phase during the development process. Early testing would have helped identify usability issues such as unclear controls or ineffective visual feedback before the final playtests. Additionally, conducting multiple playtesting sessions with each participant is beneficial, as it allows researchers to observe how user experience and physical exertion evolve with familiarity. Repeated sessions can reveal learning curves, improve reliability of exertion data, and better reflect the long-term potential of the exergame.

6.3 Future Work

To further develop this project with the goal of promoting moderate- and vigorous-intensity physical activity, a new and carefully planned testing phase should be conducted. An improved technical setup would allow for more accurate evaluation of factors such as squat gain, turn responsiveness, and movement calibration. Removing or redesigning specific game elements, such as the shooter, may also help reduce passive behavior and support higher exertion levels during gameplay.

Once the game consistently supports the desired physical intensity, new design goals can be explored. For example, investigating questions like “How do you develop a game to maintain player activity over time?” could extend the game’s relevance beyond the screen and into everyday routines.

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Questionnaire After Testing

1. What is your Gender?
2. How old are you?
3. Do you have any previous experience of exergames such as pokémon go or wii sports?

() A) Yes, several times or during a longer time

() B) Yes, but only at some occation

() C) No

I felt like I lost track of time while playing

() A) Strongly disagree

() B) Disagree

() C) Neutral

() D) Agree

() E) Strongly Agree

I felt that it was difficult to understand how the game works

() A) Strongly disagree

() B) Disagree

() C) Neutral

() D) Agree

() E) Strongly Agree

I was focused on the game

() A) Strongly disagree

() B) Disagree

() C) Neutral

() D) Agree

() E) Strongly Agree

I felt that it was easy to familiarize myself with the game controls.

() A) Strongly disagree

() B) Disagree

() C) Neutral

() D) Agree

() E) Strongly Agree

I felt emotionally attached to the game

() A) Strongly disagree

() B) Disagree

() C) Neutral

() D) Agree

() E) Strongly Agree

I felt a strong sense of being in the world of the game to the point that I was unaware of my surroundings

() A) Strongly disagree

() B) Disagree

() C) Neutral

() D) Agree

() E) Strongly Agree

I felt that the game reacted quickly to my actions

() A) Strongly disagree

() B) Disagree

() C) Neutral

() D) Agree

() E) Strongly Agree

I did not feel like I wanted to keep playing

() A) Strongly disagree

() B) Disagree

() C) Neutral

() D) Agree

() E) Strongly Agree

I felt in control of the game

() A) Strongly disagree

() B) Disagree

() C) Neutral

() D) Agree

() E) Strongly Agree

Anything additional you want to add about your experience of the game?