Heart Raiser

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ABSTRACT

In this report we introduce a game development project that was carried out within an academic setting in collaboration with a science center in Gothenburg, Sweden. Our project is a multiplayer car racing game in which the in-game speed of the players are controlled by their heart rate, intended to teach children how their heart rates can be directly affected and controlled, and how it relates to one's age. Our design method can be split up into three phases, of which the first two create the classic double diamond design process. The final result of the product was a well functioning final prototype that successfully included all highly desired features. However, there is still room for improvement within areas such as accessibility.

KEYWORDS

racing, physical activity, arduino, science scenter, public exhibit, heart rate

1 INTRODUCTION

This project was carried out within the master programs of Game Design and Technology and Interaction Design and Technologies, as part of a collaborative course shared between Chalmers University of Technology and Gothenburg University, CIU265 Interaction Design and Game Development Project. This was done in collaboration with the Universeum[1] science center in Gothenburg.

The official requirement was to create an interactive and engaging artifact that is related to a field of science involving the newest trend of quantified self, and which aims to help Universeum to attract more visitors to its facility. Therefore, we propose the following game to be installed at Universeum.

Our project is a semi-digital and electronic multiplayer racing game in which the in-game speed of the player's are controlled by their heart rate, tracked by a heart rate sensor on their fingertips. By targeting youngsters aged 12-16 (but not limited to) living in

[1] https://www.universeum.se/en/ (visited 27/10/2020).

Sweden, our purpose with this project was to create gamified learning of science in relation to cardiology, thereby hoping to raise their interest in this particular field of science.

The core of the gameplay is based on self quantification, meaning that the interaction to the game requires raising and decreasing of the pulse by performing physical exercises during the race. After the race has ended and a winner is determined, the game guesses their age based on their personal performance which is calculated and summarized from the heart rate measurements that was recorded during the gameplay.

In this paper, we describe our development process, prototyping, and play testing techniques that we utilized in more detail.

2 METHOD

This section discusses the project work process.

2.1 Process

The project can be divided into three similarly sized phases; Concept, Design, & Implementation. These are discussed more below and their relation to course deadlines are provided in Figure 1. The content of this section is presented in chronological order.

The first two phases, Concept & Design, follows a classic double-diamond (Council 2015) scoping technique where the design space is first explored in multiple directions, followed by a transition of the project into one or multiple of the more desirable directions.

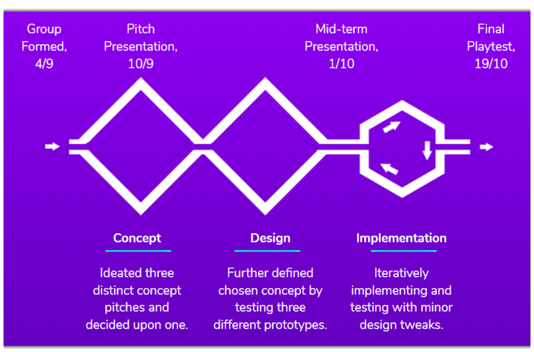

Figure 1: Overview of project process and time frame

2.1.1 Concept. The aim of this initial phase was to first ideate three distinctively different pitches and later have these presented during a pitch presentation to the university supervisors. Secondly, this phase concluded with the decision to continue with a single of the three pitches. *Heart Raiser* (then Heart Racer), became the chosen pitch to continue the project with.

- *Astronaut Survival* - A side-scrolling platformer where the user controls an astronaut that crashes on Mars. The player needs to balance various life support systems, like oxygen and energy, while having their character reach safety.
- *Thommy's Test* - The same player plays multiple iterations of Simon Says, each version with different amount of meta information and UI quality. E.g. colorless, audioless, labelless, etc. Afterwards, one can analyse how the player's speed and memory has been affected.
- *Heart Raiser* (then Heart Racer) - A two-player top-down racing game where the in-game speed of each player is decided by their heart rate.

2.1.2 Design. The state of the Heart Raiser while it was still in a pitch status required much more design decisions to be made. The team worked to create three different prototypes, each intended to test a specific aspect of different angles one could take on the original Heart Raiser pitch. These prototypes were tested internally and the final design incorporated ideas from multiple of them. The Design phase concluded after the three prototypes had been fully tested and evaluated.

- *Steering Prototype* - Each player has full rotational control of their car as it drives along the 2D top-down viewed track.
- *Drifting Prototype* - The cars drive automatically around the 2D top-down viewed track, following a pre-determined Bezier curve. If the cars attempt to take too hard corners, they will drift off the track as they attempt to return to their paths.
- *3rd person Prototype* - This 'prototype' involved playing the already existing game 3Buttons (Segerstedt 2018) while simultaneously attempting to reach high heart rates. This to both test how a 3rd person 3D game felt, compared to the top-down 2D style that was proposed as part of the pitch, and to test the physical aspect of the idea combined with a already well-design gameplay experience.

2.1.3 Implementation. The final phase of the project, Implementation, involved many smaller iterations of minor design tweaks, testing, and evaluating. Here is also where both the hardware and software of the final project were created.

Examples of minor design decisions that were taken in this stage were:

- What information do we want to show in the player UI.
- How to balance the paths of different cars.
- What the layout of the track should be.
- How should the visual doodads and backdrops look like.

During this phase, a prototype of the project was also tested by representatives of the target audience as organized by the university. Since this testing session was scheduled quite late in the design process, the main focus of the testing became more focused on tweaking the gameplay experience rather than how the core philosophy of the concept was perceived.

2.2 Division of Work

One important aspect of projects is how to divvy up the work. As such, multiple different task areas were identified that facilitated this division.

The five main areas included:

- Hardware
- Software - The Starting Scene
- Software - The Racing Scene
- Software - The Results Scene
- The Web Page

In addition to these, there was administrative work such as writing meeting agenda, and organizing & keeping track of university deadlines, etc.

3 RESULTS

This section provides a description of the final prototype and gameplay, as well as the learning and self-exploratory aspects of the game.

3.1 Final Prototype

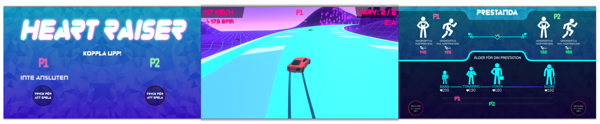

Figure 2: In-game shots of the final prototype

The final prototype is a two-player racing game. The game itself is made in Unity, and consists of two cars follow a racing track, but which may drift off-track if their speed is too high. Each player has a controller with an attached heart rate monitor and one button. The player can control the speed using their heart rates, which sets the torque of the car motor, meaning the acceleration and maximum speed is affected, and by braking, using the button. The cars follow a track on the road which is meant to mimick a natural way to steer and follows the inside of the curves. The wheels can lose traction on the road, as real wheels can, and if they do the car will start drifting. If a car goes off road, it respawns on the road after a few seconds, stopped, and then starts accelerating again automatically. In order to win, a player must have a high enough speed to outrun their opponent, but also use the brake enough that the car's speed is low enough to clear the curves and fall off the road less often than the opponent.

Other than the game itself there is one start screen which ensures that both players connect their heart rate sensors properly, and one end screen. On the end screen some heart rate data is displayed. Both players get to see their highest value registered, as well as their average during the race. Their highest values are then compared to typical highest heart rate values during exercise for different age groups: Child, Teen, Adult, and Senior. The players' data are placed in relation to these, meaning that the game makes a very simple estimate of what age their performance matched. For examples of the three scenes, see Figure 2.

Physically, the prototype consists of a laptop to run the game, two monitors for players to see, and two controllers (including connecting cables). The controllers are held on a podium or table of appropriate height for players to grasp the controller while keeping it still on a surface. The controllers, and the need to look at the screen in order to know when to brake, means that players must stay stationary and cannot run around to raise their heart rate. Instead they can use methods such as running in place or jumping. See Figure 3 for the physical setup of the system.

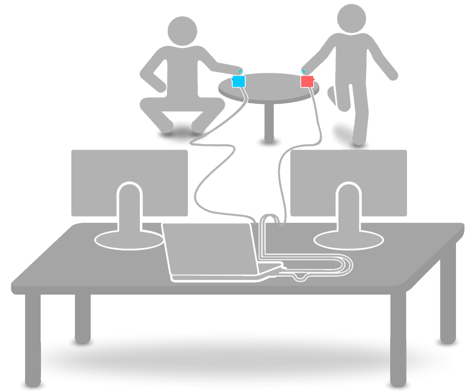

Figure 3: The physical context of the system

3.2 Gameplay Analysis

Designers and players have different perspectives when perceiving a game. The MDA model (Hunicke, Leblanc & Zubek 2004) is a useful framework which allows us to divide the gameplay into layers which build ones upon the others, perceived in an opposite order by the player than by the designer. This analysis is structured from the designers' perspective, and will also combine the usage of Gameplay Design Patterns (Björk, Lundgren & Holopainen 2003), in an effort to formalise the terms employed and put them in relation to other known games[2].

At the bottom level, we have the mechanics which support the dynamics of the game. Since MDA mechanics definition is a bit wide, we will narrow them to the mechanics definition by Sicart (Sicart 2008), identifying this way two clear *Sicartian mechanics* in our game: **pulse variation** and **braking**. The first one referring to the ability of players to alter the game state by rising or lowering their pulse, which directly affects the motor torque of their car.

The general dynamics of the game, supported by the very limited control provided by the mechanics, are those of a continuous feedback loop in which the players want to increase their pulse up to a point at which their car has higher maximum speed and acceleration, trying to balance it with the limited amount of braking they can apply when getting close to the next curve without loosing control without braking for unnecessarily long, so that their opponent is unable to drive through the segment faster.

Notice that racing games often consist of `Dexterity-Based Actions` (see figure 4), but in our case we wanted the players to be able to center on their heart rates and not necessarily on the `Challenging Gameplay` of the game. To support this, we made sure there is not a need for braking when driving with a low pulse, which becomes slowly more and more relevant as the pulse increases and the torque from the motor of the car gets higher, causing the tendency of the car to fall off the road in the curves to increase as well. This is the reason, as well, why we decided not to have full turning controls in the game, as this would instance `Maneuvering`, increasing the `Attention Demanding Gameplay`.

[2]Patterns from the online *Gameplay Design Patterns wiki* will be used, whose definitions can be found in http://www.gameplaydesignpatterns.org/. To avoid confusion, patterns will be used with the exact same name, starting by capital letters and in `typewriter font`.

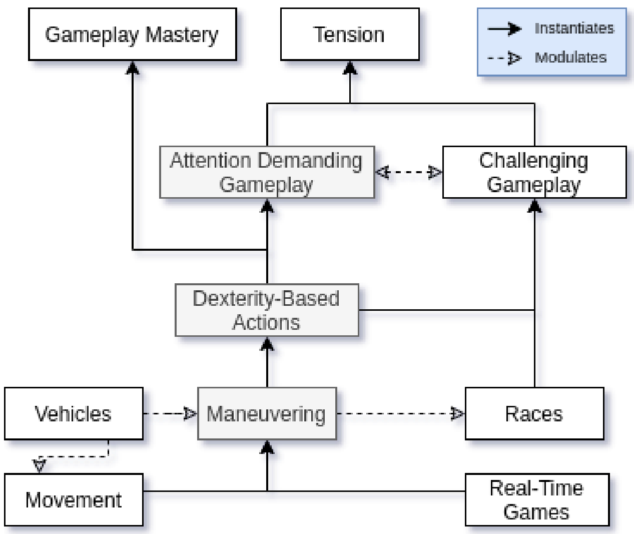

Figure 4: Gameplay Design Patterns commonly found in car racing games to support tension

The natural slowness of heart-rate variation in humans works sometimes as an example of `Delayed Effects`, which is balanced out with the braking as an immediate action to avoid the players from losing their sense of agency. In this sense, an interesting dynamic emerging from the way braking works is the **intermittent braking** some players perform to keep control of the car while controlling the speed. This behaviour comes inspired from how a real-life brake functions and it is allowed by the physical-based car movement in the game. When drifting, players can also use the brake at very short pulses to stop the lateral drift and regain traction to start speeding up again, effectively converting drifting into an instance of `Interruptible Actions`.

Most of the patterns previously described support `Tension` in the aesthetics level of the game. However, because some of them are not fully present by the lack of `Maneuvering` and a somewhat easy control of the vehicle, this pattern does not materialise fully in our game. Also, the long straight segments in our map are intended to distribute this `Tension` into small batches separated by long times, in which the players can center on raising their pulse. We believe the kind of physical activities they have to perform to raise their pulse or keep it high and the competition with another player are enough to support the game as an enjoyable activity. Therefore, coming back to the MDA framework classification of the aesthetics of games, we could say *Heart Raiser* is inclined towards **sensation** and **expression** rather than **challenge**.

3.3 Hardware

We needed controllers able to provide heart rate data and at least one button, and with an easy way to access this data inside Unity. Arduino provides easy ways of communicating data, and there are many components available for sensors and buttons. Thus, we built our own controllers using one Arduino UNO board, one simple button, and one DFRobot SEN0203 Heart Rate Sensor each, see Figure 5. By using scripts provided by DFRobot we set up a data transfer by connecting the Arduino board to the laptop and then having Unity read both heart rate and button input from the laptop ports.

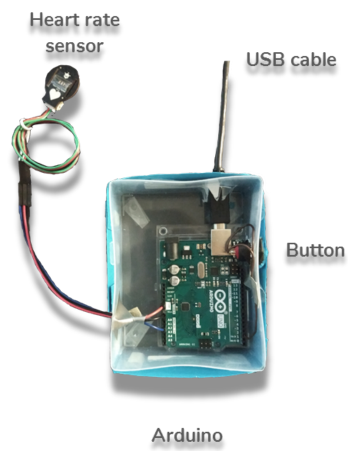

Figure 5: An opened controller

3.4 Target Audience

The project defined our main target audience as youths of ages 12-16. Our game is especially suited for those who are competitive, since the game has a clear competition component. The game is suitable for many outside of this age range as well and both adults and younger kids can enjoy the game, however since it is a game involving physical activity we believe that the ones interested will be mainly children and youth.

3.5 Learning Goals

The learning goals of our exhibit are that users should gain an understanding of their heart rate; how it can be raised and lowered, and how it can change depending on age. Rather than providing only facts and telling users directly how these things work, we aim to make users want to explore by interacting with the game, and perhaps gain an interest for the topic to learn more about it on their own.

3.6 Quantified Self

The game is played directly by data from the user. While quantified self often concerns longer periods of measurement and reflection, we created a miniaturized version during the game itself. Players always see their heart rate on screen, and can clearly see how it changes when they perform different actions like running in place or standing still. The game is long enough that it provides opportunity to experiment with different types of exercise to see whether one is more effective than another. In the longer term, players can play again to explore this concept more thoroughly, or they can reflect on the data related to age as displayed on the end screen.

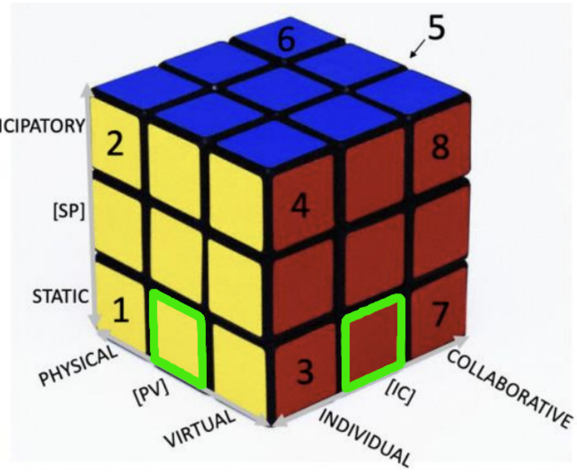

Figure 6: Our project would sit somewhere within the intersection of the inwards projection of the two remarked squares.

4 DISCUSSION

In "Designing for science center exhibitions – a classification framework for the interaction", Wideström presents the Rubik's cube model for classification of the interaction with science-center exhibitions. This model classifies the exhibits based on three axes: static vs participatory content, virtual vs physical space, and individual vs collaborative interaction. Our project would sit towards the static content exhibit, as it provides predefined information about heart-rate enhanced by the measure of the players own heart rates. The content is, therefore, not completely static but does not allow for the level of participation a more creative exhibit allows for. In the virtual-physical axis, our game fits into the middle point (PV), as it provides a racing experience in a fully-virtual world but supported by the activities performed by the players in the physical space to vary their heart rates. Since the experience of performing this activities is important for the experience of the game, one can argue our exhibit has an important physical-space-experience component to it. Finally, in the individual-collaborative axis, our project provides an experience of *social interaction emerging from individual interaction* (Karlén 2017), which places it into a middle-ground, equidistant from both extremes. The figure 6 shows an intuition for where our project would sit in the Rubik's cube model.

4.1 Accessibility

While not left completely unconsidered (specially in early stages of the design), the short time available for the development of the project prevented us from tackling the accessibility of our game with a rigorous and in-depth approach. Research in accessibility for games is reduced, but claims exist that "many of the problems in producing accessible computer games are due simply to a lack of awareness, not just of accessibility as an issue that is germane, but also in terms of what actually constitutes an accessibility feature" (Heron 2012). Taking a look at the accessibility of our game can be a good basis for future work on the project, and it is strongly relevant for the case as it is designed as a science-center exhibition.

One of the main pain-points in this sense with our prototype is the lack of sound. As it stands now, the game is completely unplayable by a blind person. This could easily be avoided, specially taking into account that our game contains cars which turn the wheels automatically. In future steps of the design of sound for the game, this should be taken into account: providing clear sounds which can give the users a feeling for the speed of the car, telling them when the wheels are drifting or out of the road, as well as more "meta" sounds like special earcons for when they are overtaken by or they overtake the other player. Color blindness has been taken into account when designing the interface so color-blind people should be able to still play the game even if not being able to tell apart the colors for each player.

Another group one could think might find a big resistance from our design would be people with mobility problems. On the one hand, our game does not require any specific way to raise the heart rate, so players with limited mobility should still be able to play it. On the other hand, raising the heart rate without being able to move can be harder and this may suppose a disadvantage for some players. Similarly, some players may have it harder to win by being able to achieve different heart-rate frequencies. From our point of view, this rather enhances the ultimate goal of the experience, which is the learning part. It may be harder to beat the game when racing against a person with different heart-rate conditions, but this fits in line with our goal to invite people to take a deeper look at their heart rates and how they are able to vary them. For example, people with reduced mobility might find out how it is possible to raise your heart rate without moving.

Lacking hands or fingers can be a big trouble towards the use of our system, which right now only supports measuring of the heart rate through the fingertip. However, bands which attach to the trunk of the body and measure heart rate exist, and they should be an alternative option to the fingertip measuring in final versions of the product. The brake control can be adaptable too, providing maybe a pedal instead, which would also be more natural, or even gesture or facial expression controls through video recognition.

4.2 Health & Safety

One concern that emerges from the core of our design is the risk for the application inducing players into unhealthy heart rates and excessive fatigue. This should be prevented in future steps of the development. The application should account for unhealthy heart rate levels and notify the users. However, this may be hard as different users may have different levels of risk. Therefore, the UI should also be improved to make sure clear warnings are displayed before the game so users will be conscious of this beforehand. If the exercise animations, currently statically shown next to the finish line rather than present in the player UI, were turned on and off to encourage players, special care must be taken such that the game does not attempt to incentive players into taking unhealthy risks.

4.3 Remote Group Work

Working in remote on this project had some downsides. Thankfully, this was something we took into account right from the start, rather than something that just showed up half-way into the project, so we could design from scratch preventing this to become an issue. Apart from the hardware input requirements, which can be mocked, our project runs as a fully virtual application which allowed for individual development by all the members of the team. We took full advantage of our remote work experience by aiming at high parallelism and independence of schedules, just interrupted by some regular meetings to keep everyone on the same page.

Despite of this, remote work is an aspect which can strongly affect the development of a game, as it requires a lot of prototyping and discarding, trial and error, and minor adjustments that may require the participation of several members of the team for them to keep in line with the shared vision of the project. This was difficult given the current situation, and many decisions and adjustments had to be taken alone to be, just later in the process, approved or discussed by other members. This may have ended undermining the creative process and the coherency and cohesiveness of the resulting product to some extent.

The usage of modern collaborative tools for development was key to the success on this. The usage of tools like GIT, Google Docs, or Discord made it possible to coordinate a full team of five developers without major complications which would prevent the project from getting to an acceptable state of completion.

4.4 Future Work

Especially valuable to remark on in the topic of future work is the addition of sound, together with the expected refinement in case of taking this product to a production state and that should take in account the topics discussed in sections 4.1 and 4.2. Other planned improvements include a better hardware support, with increased accuracy and reliability in the measuring of the heart rate, and maybe different tracks to allow for better replayability.

On the side of the data, we would like the application to be able to save the heart rate data from the participants in the exhibit, displaying the average and top heart-rate among all the previous players, and maybe even offering the option to introduce the age in some way so the scale in the results screen gets adjusted correspondingly. On the side of the web page, it would be interesting to share this stored accumulated data and maybe provide with some more insight on research about heart rate.

One of our proposals for future development is a mobile application to log in to the game locally in order to encourage return visits to the facility, provide and save data summaries for the person, and to collect data from the users. The game should be played locally at Universeum facility, therefore, the players must log in to the game using this phone app and by scanning a QR code that is displayed on the screen. The QR code should be re-generated after each play session. Before visiting the facility, one could download the Universeum Heart Raiser Authorization application from Google Play / Apple Store. Upon installing, they can register an account by providing a username, and possibly the age, as well as the privilege to link a social networking account in order to share personal results, or even invite friends, thereby recruiting more people. Upon login, the game identifies them by their user names instead of "player 1" and "player 2". While they are playing, their heart rates are measured and visualized, and shown at the end of the game. Upon finishing the game, the personal result is sent / saved to the user's device accordingly so the player can look at the result later, also to view analytic data in forms of charts such as how much of a personal improvement happened since the player played the game last time. Universeum could also collect data from the users of their interest such as how many users do they have registered on this application and what were their results.

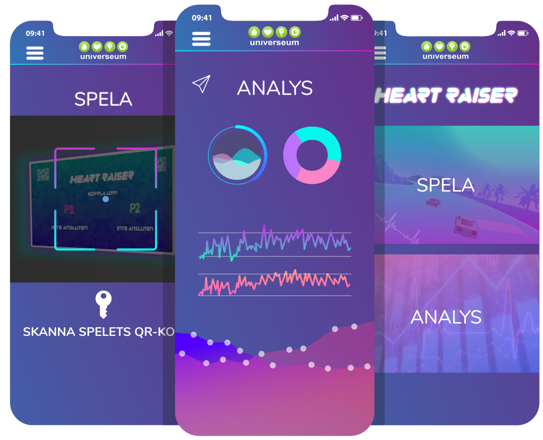

Figure 7: Sketch of possible future phone application

5 CONCLUSION

We were able to achieve the initial goals that were set during the design of the game. The overall project turned out to be really fun, innovative and educational, more than we expected.

The engine of car's acceleration and speed being controlled by the players heart rate made it fun as players would have to jump or run in place to increase their heart rate, and by extension, the speeds of the cars. As an innovative element we provide the substitution of the steering control of the cars with the players heart rate. For the educational part, players learn about their heart rate in depth as they would learn to control their heart rate be it to increase or decrease when needed. This in turn helps them to gain an indirect conscious awareness of their own heart beat and hopefully rises their interest for heart topics.

Despite of having just two months of time, even with possible improvements as described in section 4.4, the project can be considered successful with respect to our design goals (being it a *high-fi* prototype rather than a full, polished product).

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