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Designing Future Exergames: Sportification and
Bio Connection

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Designing Future Exergames: Sportification and Bio Connection

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Summary

Exercise game, also known as exergame, is a term that describes video games that involves physical exertion, in other words, a combination of fitness and video games. Over the years, both video game and fitness industry has evolved and grown. On the one hand, a phenomenal new game category called e-sports arose, dominating game market and threatening the traditional sports. On the other hand, technologies such as sensing technology, wearable devices, artificial intelligence, start to take a big role in fitness industry. Nevertheless, exergames has no significant evolution in terms of game concepts and core technology since 2000, and it is showing its limitations in both entertainment and workout effectiveness. The research aims to explore the design of future exergame experience. By introducing two concepts: Sportification and Bio-connection, we are trying to redesign exergame experience to make people actively engaged into the gameplay and meanwhile secure scientific and efficient workout. One exergame was created to testify part of the concept, after receiving feedbacks and valuable insights, we created another exergame which was implemented with more complete concepts for further evaluation. The results show positive feedback on the fun of gameplay and workout efficiency alike.

Keywords:

Exergame Design, Bio Connection, Game Mechanism, Innovation, Sports

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ZHOU QIWEI

Contents

List of Figures

List of Tables

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Chapter 1

Introduction

1.1. Background

Insufficient physical activity is one of the leading risk factors for death worldwide, according to WHO [1], 1 in 4 adults, and 3 in 4 adolescents do not currently meet the global recommendations for physical activity. Entertainment activities such as playing video games, watching videos, playing mobile phones have made people spend more time in front of a screen than ever before, thus form a sedentary lifestyle. Another alarming sign is that people are losing interest in sports. According to Deloitte [2], ratings for the Summer Olympics, the NFL, and the Premier League have been declining at 15 percent, 9 percent, and 19 percent, respectively. Not only people are watching sports less, but people are also playing sports less. In the United states, 2.6 million fewer kids are playing basketball, soccer, baseball, and football from 2008-2013 [3].

In contrast to the downturn of traditional sports, esports, a competitive video game category, is growing at an exponential rate. a study from Newzoo [4] estimates that for 2020, there will be 589M who will watch esports.

With a growing number of people, especially the younger generation, are becoming more engaged in video games than sports, it seems that exergames, the combination of game and exercise can be part of the solution. Though having some limitations, it is generally acknowledged as an alternative to physical exercise, especially for people who are not motivated to play traditional sports.

1.2. Motivation

I was born in an era of ubiquitous technology, from my childhood, internet, computer, mobile phones were so familiar to me as if they ought to be there. People

(https://newzoo.com/insights/articles/global-games-market-reaches-137-9-billion-in-2018-mobile-games-take-

half/)
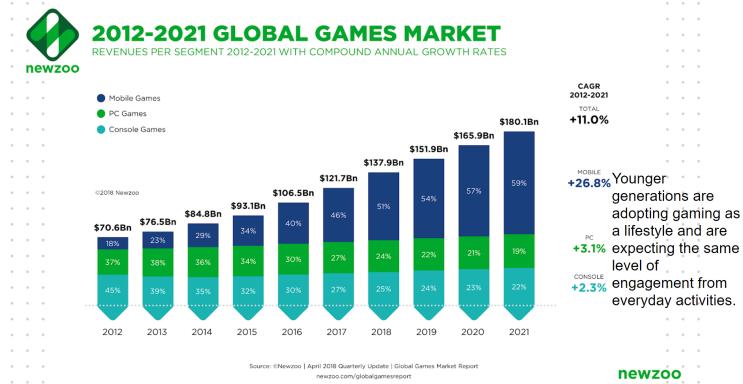
Figure 1.1 esports growth

who are born since my generation, are called digital natives.

Like many other digital natives, I got used to living in the comfortable cradle created by technologies. I am obsessed by digital entertainment especially video games, which gives me strong sensory stimulation as well as the sense of social connections. Just like many other fellow gamers, I formed a sedentary lifestyle. While being aware of the health risks, I did not pay much attention to it until some health issues started to affect my life, including overweight and severe back pain.

However, exercise is a painful experience for me, both physically and mentally. Physically, because lack of regular exercise and professional instruction, it usually cause muscle tension or even injury. Mentally, I found exercise intolerably boring. Since I already get used to digital entertainment, I naturally expect the same level of engagement in other daily activities, yet tedious and repetitive exercise can never give me that much stimulation. My attempt to form a habit of regular exercise was never successful, but I am not the only one who has the difficulty. According to Australian fitness industry's report [5], fitness clubs are facing with 50 percent churn rate within 12 months.

Therefore, as a combination between fitness and game, exergame seems to be the right solution. However, it turned out to be useless for me. I have been

2

trying several popular exergames on multiple platforms since young, such as Xbox Kinect, fitness boxing, Beat saber and so on. Most of them have one problem in common: the design of the game is hugely based on physical movement, which means the game elements are nothing but a visual aid to exercise, I can easily get bored with game without depth in game design. Another problem is that most of the exergames, although do raise the activity level, fail to reach the effectiveness of a real physical exercise. In the end, it is neither fun as a game, nor equivalent as a workout.

Having tried several methods to keep myself motivated to exercise but eventually failed, that was the time when I started to think what I can do about it as a media innovator. I want to push the limits of exergame design, by combining technology and novel game design concepts.

Chapter 2
Related Works

2.1. Wii fit

In the game category, there is one called sports video games, in which the game contents are simulation of sports. It is also the most common exergame category because the easiest way of turning physical exercise into a video game is by simulating the exact movement of an actual sports.

One of the most well-known sports exergame titles is Wii Fit. It was released on December 1, 2007 on Nintendo Wii console, until March 2012, it had sold 22.67 million copies, becoming the third bestselling console game not packaged with console, and the most successful exergame ever. This was an extraordinary achievement, before Wii fit, there was no exergame on console that can compete with traditional video games, not to mention having the title on the sales rank. And it was since then, the exergame started to become a big business.

To play Wii fit games, the player needs to use the Wii fit balance board accessory, which is a device that can detect the body movement to some extent by measuring the player＇s gravitational center point. The shape of the balance board looks like a body scale, and on the bottom of the board, 4 pressure sensors are located on each corner.

Wii fit provides four main exercise types: balance training, aerobic training, yoga, and muscle training. The gameplay is rather simple, most of the mini games have a Wii trainer as an instructor to guide the player do a series of movement, with some visual aid such as a cursor that indicates the position of the player＇s balance center, or a bar that tells the player when to do movement and when to rest. Most of the movements are designed based on real exercises, such as Yoga postures, muscle training, and the balance board can prevent players from cheating. In the later released Wii fit plus, a more personalized training

(https://www.taminggaming.com/game/Wii+Fit)
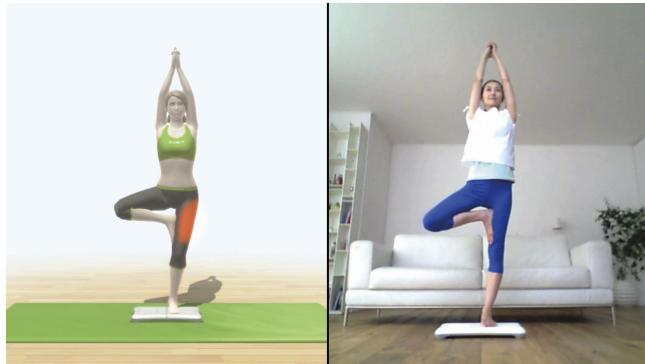
Figure 2.1 Wii fit

feature was added as well as more exercises, there is no multiplayer feature in
Wii fit, although multiplayer mode was added in Wii fit plus, it does not support
simultaneous multiplayer, which means players have to take turns to play in this
mode.

Although it has been called exergame, it is more focus on the exercise part than
the game elements, just like how the game director of Wii fit Hiroshi Matsunaga
has described the game: ″ a way to help get families exercising together ″.
Wii fit systems are also adapted by medical facilities, nursing homes and fitness
clubs. To sum up, Wii fit is a product that aiming at providing visualized exercise
instruction on a home-based digital device. Generally, Wii fit was well received by
the video game critics. The criticisms mainly focus on limitations on the exercise
efficiency and personalization, the lack of entertaining elements and lack of social
experience.

2.2. Kinect Sports

Following Nintendo, in 2010, Playstation 3 and Xbox 360 released their new hard-
ware for motion sensing game, Xbox Kinect and Playstation Move.

Xbox Kinect integrates with a depth and motion sensing system which captures
and analyses the infrared lights from the objects. By using edge detection method,
it differentiates closer objects from the whole image. With assumption that only

human will be moving in the image, it can recognize human shape and then it creates bones and understand motion.

PlayStation Move on the other hands, is a set of wand controller with a LED on the head which can glow in any color. The color is selected by the system to be an active marker for the camera to track the position and size of the light. Thus, the system will get the spatial information of the controller in 3 dimensions.

Both two system was designed to detect player motion and transform it into game input. With a more advanced motion sensing system, it enables more possibilities in the gameplay, for example, simultaneous multiplayer, full body motion games, shooting games and so on. From 2010, a great number of sports motion sensing games were released on both platforms, these games are generally similar in terms of way of control, gameplay, and exercise efficiency, therefore here I will take one typical game, Kinect sports, as a case study to analyze.

Kinect sports is the flagship motion sensing game on Xbox 360, which was released on the same date as the Kinect, it includes 6 sports simulation and 8 mini games. Unlike Wii fit that has a clear goal of getting people exercise in a relatively instructed and scientific way, Kinect sports choose to be a party game, with huge emphasize on the multiplayer mode. Players can play all the mini games in multiplayer mode both online and locally, also with both co-o and competitive mode. It is a game designed to be played with family and friends. One interesting feature is that the camera will record the video when players are playing, and they can see the video clips after playing and it can be shared online. Although the game design is still quite simple and lack of repeatable playability, all these social features made Kinect sports more entertaining than Wii fit.

On the exercise part, however, it is even less effective than Wii fit. Firstly, the game is not designed strictly based on sports science, there is not any structural instruction on how to and how much the player should play. Secondly, the motion design in the game is a rough simulation of physical movements which is oversimplified and mostly ineffective, for example, the tennis movement is to swing the arm as if you are swinging the racket, however there is not any weight on player ’ s hand, and no lower limb movement is required, the physical exertion is very limited. Thirdly, since the motion sensing system can only detect position, it cannot correct player posture or check the how much force the player is applying to his or

(https://www.thegamereviews.com/article-5851-kinect-sports-season-one.html)

Figure 2.2 Kinect sports

her arms, which means sometimes the player can control the game without doing the full movement or with a minimal force.

There are some other games which use Kinect or Playstation Move that involve physical movements, but most of them are not even close to be called exergames, they are just traditional games that use motion sensing, so they will not be discussed here.

To sum up, Xbox Kinect sports is a launch title game designed to demonstrate the motion-sensing capabilities of Kinect, with focuses on multiplayer mode, it became an entertaining family party game. However, the exercise effectiveness is doubtful.

2.3. Zwift

Zwift is an indoor cycling training program that enables people to use bike trainer to train and compete in virtual world. Zwift game was firstly released in September 2014 and commercialized in October 2015.

Zwift does not manufacture any tangible products, instead, it integrates with quite a lot of third party equipment, for example, to use Zwift, users need to have a smart bike trainer(or a traditional trainer with speed and power sensor), a bike,

and a device to run the software. By using ANT+ and Bluetooth, the system will transmit data from the bike trainer including speed, power, torque, and turn them into the speed of the virtual bike in game. There are some other additional equipment that can be integrated too such as climber, a device that can increase the slop of the front wheel, smart watches or heart beat sensor, which can display the heart rate during the game, and fan, which gives wind simulation during the cycling.

(https://www.bicycling.com/news/a29860926/zwift-to-develop-hardware/)

Figure 2.3 Zwift

Zwift is a pure simulation of real cycling, all the in-game characters are dressed like cyclists, all game routes are 3d models of real-world cities, or natural scenery to give an immersive virtual cycling experience. There is not much game element in Zwift, the focuses are on the training and exercise part, which is successful, because the hardware needed to use Zwift are professional fitness equipment, with addition to the resistance and climber feature, player can have a pretty solid exercise.

Apparently, Zwift is for cycle lovers who want to have the cycling experience at home due to some limitations and concerns such as traffic, safety, weather and so on. Despite having little game elements in Zwift (there is nothing else the player can do apart from peddling), it does bring some new entertainment elements to the indoor cycling experience, which is the social connected experience.

By using Zwift, the player can cycle together with any Zwift user online all over the world, there are display of their ranking, heart rate, power, and players can

also communicate with each other in real time through Zwift app. There are also events held by Zwift that allows massive online multiplayer, to compete in the same virtual world no matter where they from.

To sum up, Zwift is a virtual training program that designed to simulate cycling experience, with strong focuses on exercise and social experience.

2.4. Dance Dance Revolution

Dance Dance Revolution is a music video game series produced by Konami, which was first introduced in 1998 in Japan. It was the first game in rhythm and dance genre that has been extraordinarily successful both inside Japan and overseas.

There are two parts of hardware that consist of the standard DDR machine, the cabinet, and the dance platform. Cabinet is main body part which has display, speakers, and lights. The dance platform is a metal stage that has several plastic pads which has orthogonal direction arrows on them. Each pad embedded with pressure sensitive switches, that can sense the pressure and turn it into game control.

(https://www.bicycling.com/news/a29860926/zwift-to-develop-hardware/)

Figure 2.4 Dance Dance Revolution

Following a series of visual instructions (the arrow) on the monitor, players need to step on the correct arrow on the dance platform with a certain rhythm. Although the game rule is quite rigid, there is not only one way to play DDR. There are several play styles acknowledged by fans, one is called "freestyle", in

which player often use flashy and complex techniques including developing their own routine dance steps and body movements during performance, in this play style, players tend to choose lower difficulty to avoid concentrating only on getting the steps correct so that they can perform more freely with their emotion. This play style is closer to the original design intention of the game: to combine music, rhythm, and dancing. The other play style, however, is focusing on extreme speed and accuracy, which is often referred as "PA (perfect attack)" style. PA players often minimize any unrelated movements and focus on moving legs as fast and as accurate as possible. Therefor they will lean on the rail behind them and only move their legs. In fact, most of the DDR competitions are using this play style, so the players who can play the most difficult song with best accuracy will win. However, this play style is often criticized by freestyle players and fans because they think it takes out the fun part of the game: the dance, making it a pure rhythm game that only depends on muscle memory and reaction and at the same time reduces the attractiveness for spectators.

On the exercise part, although DDR was not intended to be an exergame, many players has reported weight loss after playing DDR. There was not enough quantitative research on the average calory consumption of this game, but the amount of active movement required to play implies that DDR provides at least some degree of healthy exercise. The game was later introduced to several schools as a part of physical education.

Since early 2000, DDR has gained large number of popularity and formed a passionate fanbase, however, with the decline of arcades industry and dance rhythm game genre, DDR have become much more niche over the past few years. In 2017, there are only 50 machines remaining in the US.

2.5. Discussion

In the above paragraphs, different types of exergames were introduced, in this part, the limitations of these games will be discussed which will lead to possible solutions in the next chapter.

Sports exergame is the most common type of exergame. One common problem in this genre is that they are not as entertaining as many other game categories.

In a research from Dalhousie University and Carleton University [6], researches did a rating on the "Fun" of exergame and compare Wii fit to sedentary games, the result shows that Wii games are not as fun as traditional games.

There are two main reasons why. First is that sports exergame do not provide game fantasy, which is one of the biggest reasons why people obsessed with video games.

In most of other game genres, fantasy is at the core of game design, It allows player to create, to destroy, to interact, to act, to explore⋯ , for example, putting player into a story that they will otherwise never have a chance to experience in real life is game fantasy, but fantasy is not necessarily created by story or narratives, the core is to escape the reality, to enable players to do things they can't do in the real world.

The sports exergame, however, cuts the game fantasy, because players are doing the exact same movement of what they will do when playing the sports in the real world, and the game characters resemble the same movements too. In Kinect sports player can at least do movements freely and it will actively affect the win or lose of the game, however in Wii fit training, even the activeness are cut, player can only do the exact movement as the virtual instructor do, it becomes a pure exercise with visual instruction. Not only are there no game elements, but also without any narratives or story. Although this is not to say it's meaningless to simulate real sports, because for some players there might be some limitations for them to play the real sports, that's when sports exergame become an alternative activity, but overall, this type of exergames don't provide enough game fantasy experience as most of the other game genres do.

The second reason why they are not entertaining is because the game design itself is oversimplified, for example, most games on the Kinect sports neglect the lower limb movements, which means if it's a ball game player don't need to care about positioning, only a single arm movement to hit the ball is all the controls. This is probably because the game designer wanted to focus on showcasing the new way of interaction so the game dynamics was simplified to be easy and friendly to anyone even if they haven't play much game or sports before, which is quite successful, but at the same time, each sports game become a short mini game with minimum skills and strategy needed. If the game design is over simplified, it often

results in player getting bored quickly because it is unable to constantly provide novelty and excitement to the players, it will eventually become as repetitive as actual exercise. In a report from AHKC (Active Healthy Kids Canada) [7], researchers did a systematic review on the effectiveness of exergame among kids, and the results shows that kids found exergames appealing but the appeal wears off over time, and many don＇t stick with them. This research shows the sports exergames might not be games that people can enjoy playing at regular basis.

Rhythm games have their own problem too. The genre has never reached a mainstream popularity, mainly due to the hardcore game mechanism itself, Players have to follow the rhythm which is the only way to be good at the game, any wrong notes or notes that are not on the correct timing will be considered a mistake. Therefore, practicing in rhythm game is more like a mechanical repetition to train reaction and form muscle memory which results in a repetitive and passive gameplay. These features make rhythm games eventually become a niche game genre that has of a stable community of core fans but hard to grow and keep casual players.

Apart from the gameplay perspective, the exercise efficiency is another common criticism on exergame in general. From what has been introduced, Zwift is the only exergame that can be equivalent with real exercise because it integrates with professional fitness product. However, all the other console exergames, including Wii fit, which clearly aims at fitness and has been commercially successful, has been criticized with low exercise efficiency. In fact, from existing research, there is no evidence showing console exergame can be equivalent to real exercise.

In a research conducted by Children＇s Nutrition Research Center, Department of Pediatrics [8], researchers organized two groups of kids, 84 in total, aged 9-12, one is the treatment group, which was given Wii consoles, Wii fit exergames and the peripherals needed to play the games. The other group is the control group, which was given the same console but with inactive games. After 12 weeks of intensive tracking with sensors and questionnaires, the results showed that the kids in the treatment group did not show a higher level of activeness than the other group, kids in the active game group got an average of 25 to 28 minutes of moderate or vigorous physical activity each day ― compared to between 26 and 29 minutes in the inactive video game group.

To sum up, first, currently the exergame are extremely limited in terms of game genre and the game design, which makes most of them not as entertaining as other traditional games. The games fail to make use of the strength of the game to make the player escape the reality, instead, it simply reproduces the dry and repetitive experience of a physical exercise or a sports in a virtual game with superficial game dynamics that would quickly lose its attraction after the initial novelty wears off.

Second, with problems such as lack of sports science, lack of guidance, not enough movement required, the possibility to cheat, and lack of additional hardware, most of the exergames do not provide the amount of physical exertion that equivalent with a real exercise.

Currently there is no exergame that has both entertaining game dynamics and effective workout capability, it is either not fun as a game, or not effective as a workout, or neither. Exercise and video games were never truly combined. These limitations listed above leave a space for further research and improvement.

Chapter 3
Concept

In this chapter, two main concepts will be introduced, Sportification and Bio connection. The concepts will remain theoretical and high-level in this chapter, the implementation of these concepts will be shown in the latter chapters.

3.1. Sportification

3.1.1 rethink of gamification

As discussed in the last chapter, the reasons why most exergames are boring are related to lack of game fantasy, oversimplified game mechanism, limited game genre··· these imply that there might be problems within the process of how the exercise are gamified into a video game. But before getting into the details of the current method of gamifying sports, the meaning of the word gamification mush be clarified.

In recent years, the word gamification has become a buzz word. People from different industries try to use it as a tool to make their product or service more fun and exciting. But what most people do is to simply put some "game elements" such as points, badges, and leaderboards, or some animation and game-style visuals and then hope the "game elements" would magically turn those boring tasks into a fun game. But unfortunately, this is a huge misconception about gamification. All games have game elements, yet only a few games can be called great games, so there is no reason to believe that just by taking these fragmented game elements from random games and pour them into product will make the product fun and exciting.

The secret under it is that a good game is not only about the game elements but more importantly, about how the game mechanism motivates the player '

s core drive. There are two kinds of motivation, one is extrinsic motivation, including accomplishments, ownership, and scarcity, these are the ones that people do for a reward and goal and normally it is implemented through add-on game elements. The other one is intrinsic motivation, such as empowerment/creativity, social influence, and unpredictability, these are things people do just because it is enjoyable, and they do not require reward, this one is achieved by the game mechanism itself. Great games usually focus more on the intrinsic motivation rather than extrinsic motivation. Because intrinsic motivation is from the human instincts, such as the curiosity to explore and learn, the creativity to build and craft, and the strong desire to win. It is a subjective initiative that keeps people actively engaging in the gameplay even without a reward. In this case everything that the player do is because they want to, not because they feel they have to. On the contrary, extrinsic motivation mainly focuses on setting goals and mission for the player and keep giving rewards and punishment. Player will be more motivated to accomplish goals, but it does not necessarily change the fact that the mission itself can be boring and people might not be willing to do the task once the reward is reduced or removed. In this case, players are much more passive, the motivation rely hugely on the rewarding system.

To sum up, gamification is an extremely complex theory, good game design consists of methods to motivate players ' core drives especially from intrinsic factors.

3.1.2 Game Sportification

If we use the same model to analyze exergame we will find that current exergame design always starts with an exercise, then just copy the same exercise mechanism with game elements such as some points, scores, and visual instructions. The problem with this methodology is that the idea of exergames are created based on an assumption that exercises are generally boring, therefore by reproducing the boring exercise mechanism in a game will not help fundamentally change the experience. Putting scores, points, visuals instructions can help but as discussed above, they are extrinsic motivations which are passive and superficial, the intrinsic motivation, however, are completely neglected.

In a word, gamifying exercise method uses exercise as the starting point, then

add game elements upon it, the core of it is exercise, rather than game. That is the main reason why it lacks game fantasy and game dynamics, which further explains why it is boring.

But instead of gamifying sports, we can look from the opposite direction, which is to sportify game. Because there are great games that already exist, they have good mechanism which can be adapted and turned into exercises. In this methodology, the game is the starting point, while remaining the game mechanism, replace the game input with a physical movement. This method makes the game at the core of the design, which guarantees the playfulness. Following this idea, a game sportification pipeline was made.

Game Sportification Pipeline
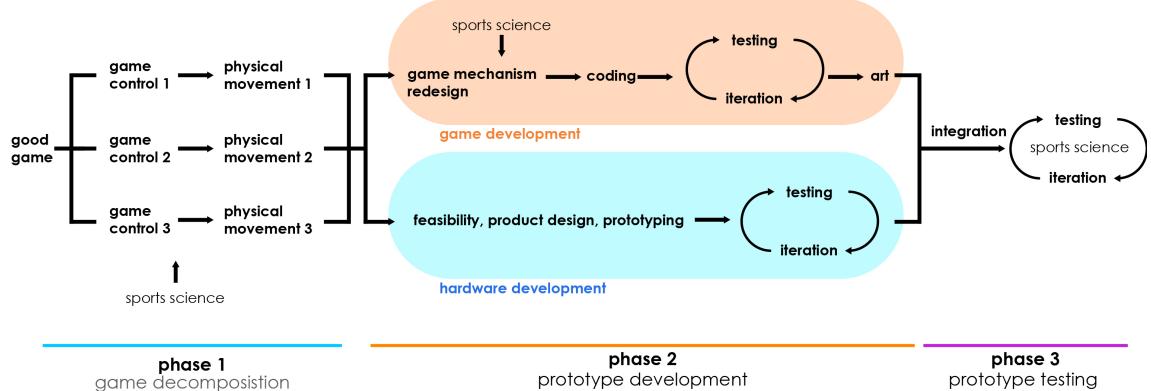
Figure 3.1 game sportification pipeline

This pipeline consists of 3 main phases, in the first phase which is called game decomposition, an already existing game with a good game mechanism is used as the starting point, then all the game controls are listed, with the help of sports science, some of the game controls will be turned into physical movements. There are 3 main considerations here in turning game controls into exercise, Firstly, the importance of the game control will be evaluated. This method will prioritize the fundamental game controls, for example, in most games, character movements are the most important controls, then is the secondary action (depending on game category) such as attack, dodge, jump, and defend. After that Others such as using

power-ups, items, and magic spells, checking game map⋯ are less prioritized. This can make sure the most important and fundamental controls will be sportified. Secondly, the type of physical movements must be efficient in terms of workout. This is where sports science start to play an important role in this methodology that could prevent the exergame end up being entertaining but not effective as a workout. Normally, those movements that already been acknowledged as workouts will be firstly considered, especially workouts that require equipment because usually fitness equipment provide weights and resistance. But the movements are not necessarily existing exercise, because the final evaluation is based on the outcome of the physical movements, which is to say, if the movements is aerobic, we can evaluate some general data such as calory consumption and hear rate, if the movement focuses on muscle training, we can measure the muscle mass. Therefore, even if the movement is created just for the game, it will be accepted if it meets the requirements of the workout efficiency. Thirdly, the intuitiveness of the movement. Game controls are not just turned into random movements, to increase the immersion, it is preferable to find the movements that has some connection with the game control. For example, movements such as running, pedaling are more related to linear, continuous movements, so it feels more intuitive if these movements control the speed, power, direction. Strength training such as lifting, punching, rowing, are more related to one-time, instant movements, so usually they fit with game control such as jumping, attacking, shooting. This intuitive experience can also be strengthened by the art design of the game, for example, there can be some animations of the main character doing the same movement in the game that resembles the physical movement that player is doing.

The second phase is developing the prototype. Here the pipeline divides into two parts, hardware development (if any) and game developments which work in parallel. In hardware development, there is evaluation of feasibility, if the hardware needs to be designed from scratch or a modification on existing fitness equipment, after that is product design and prototyping, testing and iteration will be processed after the hardware prototype finished. On the game design part, the first task is to redesign the game mechanism based on sports science. Here redesign does not mean to completely change the mechanism, the idea is to keep the essence of the game design but make some modifications to adapt the workout. Because

games are not designed to be played by physical movements, simply changing the way of control from keyboard to body movements will not be scientific in terms of workouts, because exercise has its own requirements too, for example, if the we are using lifting dumbbells to replace the shooting action in a game, and if in that game player always need to shoot 50 times in a minute, it means player will need to lift dumbbells in the same frequency, which does not make sense in terms of workout and it can cause muscle fatigue and even injuries. Another example is about the pacing, if the reference game, one match is 5 min, and we are using peddling to control the game, that will mean each session is 5 minutes, which will be considered too short for a cycling exercise. Some people tried to use fitness equipment to just hack in video games and control the character, but it obviously will not be a scientific way of exercise. This is why the adaption process is extremely important because it is decisive point of the whole method to keeping both the playfulness from the reference game and also secure the efficiency of the workouts. After this process, the beta version of the game will be made and tested without the hardware, after that is the art design and implementation.

The final phase is the integration and testing of the whole system. Player will be able to test with a working prototype that provides the full experience, and the final evaluation will be focusing on the level of engagement and workout efficiency.

In summary, in contrast with the sports gamification approach, game sportification is a new methodology to design exergame, which chooses the game as the starting point of the design. This method aims at minimizing the passive and repetitive feeling of exercise and giving an engaging and motivating game experience. While preserving the essence of the game to the maximum extent possible, it also actively uses sports science to modify and regulates the design. This approach helps design exergames that are both entertaining and effective in workouts which will be applied in the prototypes in later chapters.

3.2. Bio connection

3.2.1 Introduction

Bio-connection is the second core concept, it started with the thoughts on how to make use of bio data. Recent years in fitness industry, the use of technology has become more popular. Smart scale, smart phone, smart watch, speed sensor, EMG suit··· devices are becoming smart and connected, wearables that embedded with sensors are sensing human body in all aspects and constantly providing bio data, our life can be monitored and analyzed 24 hours, from calory consumption to sleeping behavior, from training tracking to nutrition balance.

Showing numbers seems to become a trend, In training apps or some exergames, we often see it show users ’ real-time heartbeat, calories, in fitness apps, we can find a whole profile page full of numbers, beautiful line charts and bar charts, but no matter how beautiful the information visualization design was done, it doesn ’ t change the fact that they are still cold and dry number that serves the only mission that they have : to inform. So eventually, all the data end up here, from sensors, to numbers. However, for users, only knowing the numbers are not enough, they should also be able to understand the meaning of the changes that they are making, be guided and be motivated.

Therefore, instead of leaving the bio data as cold and dry numbers, I thought of giving the numbers meanings. Game came into my mind again. In traditional role-playing games, the character usually has a table of attributes, where there are also numbers such as damage, armor, speed, magic ··· what ’ s unique about game is that it does not focus on the numbers themselves, instead, it reflects the numbers into game experience. For example, when player level up, the damage increases, but normally player will not feel the change just by looking at the numbers, the change on numbers are reflected on the experience of combat, so instead of directly telling the player that they become stronger, they can actually feel the satisfaction by themselves when the they kill monsters more easily, when they can use more powerful skills, or when the visual effect of their attack looks stronger. The experience-centered data design in game gives meaning to numbers, making them responsive game elements that gives satisfaction and also guidance.

If we look at the health data, we can find that they look astonishingly similar to

the character attributes in the game. So, the idea came to mind: to turn bio data into game elements, making them not only information to know, but something that can directly influence the gameplay. This way we can take the data one step further, from sensors, to numbers, and to games.
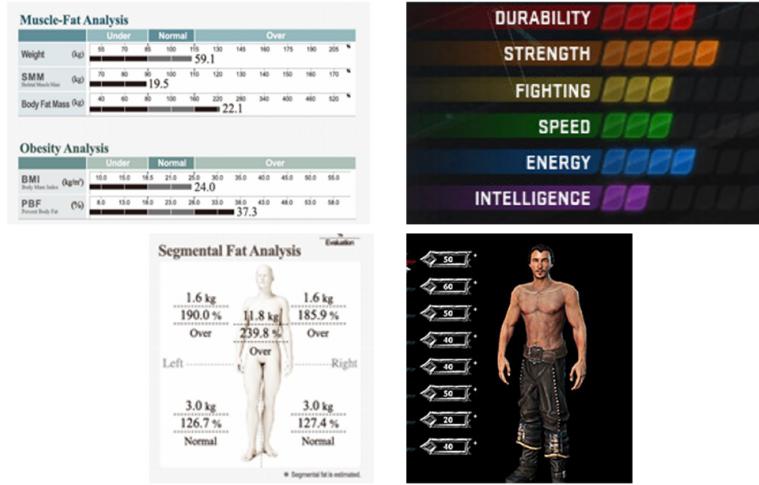

Figure 3.2 Bio data and Game character attributes

By making use of the sensors we can turn different bio data into game elements, imagine if the player has a stronger leg then the character can move faster, if the player has a stronger arm, the character deals more damage. If the player increases durability, the character has more armor. Every small change on player's body, will directly reflect in the game play.

This concept has two main advantages. Firstly, it increases the playfulness and motivation for the player. The core idea of bio-connection is about growing, the character will grow and evolve with the player's physical body. Therefore, as the player exercising and getting stronger, so does the character. In this way, the body changes are reflected in the game experience which is much more intuitive and fun than just looking at the numbers.

In addition, we can modify the growth rate of any game data that related to bio data. This is an important feature, because for many people who do exercise there is a big obstacle, they do not see any change of their body in a short time, so after a while they get frustrated and give up exercising. That is because
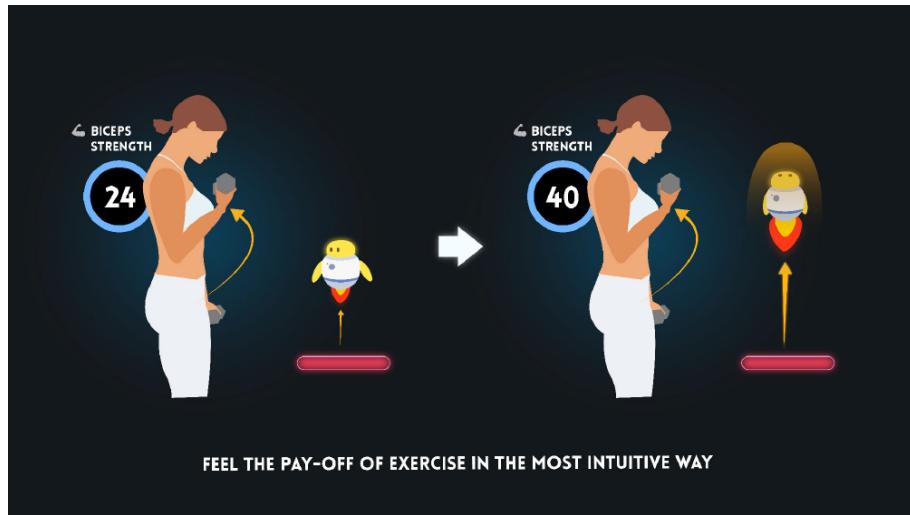
Figure 3.3 Reflect body change in the form of game experience

sometimes the change is too small to see in certain stages, some might require months of training to see a change. But If we can modify the growth rate of the character ability, we can amplify that small changes in the form of game fantasy. For example, if we increase the growth rate of character skill upgrades, then even a small improvement of BMI (body mass index) can have a significant upgrade of skills for the character. This can make player feel the changes and satisfaction through game experience, which otherwise will not be seen from their body by naked eye. And this growth rate can be flexible according to what stage is the player at, for example, the growth rate can be high when the player are struggling and need the most motivation, it can also go lower to become more challenging when the player need more training. This method is widely used in game design, to motivate players in different stages like the diagram showing below.

The second advantage is that it also provides guidance. Only by looking at the number does not tell the users in what direction should he or she improves, and for each time, how much exercise is appropriate. But by turning the biodata into responsive gameplay, the game design itself will guide the player to do workout correctly, without telling them the theory and numbers behind it. For example, if in an aerobic exergame, we implement real-time heart rate as a game element, when the heart rate is below the designated level, the character will lose hp, if

Figure 3.4 modify character growth rate

it's within the designated range, the character will charge its ultimate skill, and if it goes beyond the safety range, the character will go overheat and stop moving. In this system, the game motivates the player to raise their heart rate to an efficient level and at the same time preventing over exercise which could be harmful, without showing any numbers or instructions, the whole process is drove by the desire of winning the game from player.

In this way player can be totally immersed into the game and get a proper exercise guided by the game design, without having to know how the sports science work, instead, the system behind the game will do the job, which is a program that process and analyze the bio data based on sports science then give back the feedback to the player in the form of responsive gameplay.

As the picture showing below, players are in the bio-connected feedback loop

to keep improving in the right direction in a playful and intuitive way.
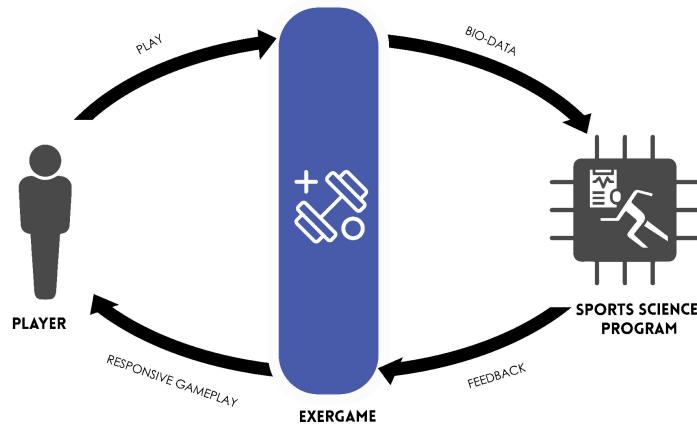
Figure 3.5 feedback loop

3.2.2 Examples of Bio connection

This part will be focusing on elaborating the possibilities of what types of data we can use and how these data can be connected to the exergame.

First example is the real-time heart rate integration, which was mentioned before. For aerobic exercises, heart rate is one of the most important indexes, and the heartbeat sensors are already immensely popular in the market, it is quite common that people monitor their heart rate when doing exercise. In order to reach moderate to vigorous exercise It is suggested to maintain a certain level of heart rate, therefore the game design should favor the player when they maintain the heart rate, for example, giving power-ups, charging skills, and at the same time, the game should give negative feedback such as character dies, slow down or loses power, when the player's heart rate goes to too high that can potentially be dangerous. Real-time bio connection focuses more on reflecting a dynamic body change during the workout session.

Nonreal-time bio data can also be integrated. Nonreal-time bio connection is more focusing on a long-term body change which are insignificant in a short time and reflects or amplifies the small changes in the game experience. Calories, for example, is another commonly monitored bio data, which is normally estimated by
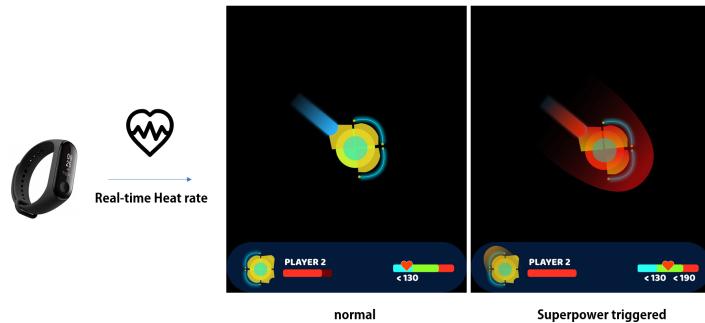
Figure 3.6 hear rate connection

wearable devices such as smart watch or smart band. In this example picture, daily calories consumption is turned into experience that can level up the character. It can also be other game elements for example, currency, materials to craft weapons etc.

Steps are the most common data that almost all people who have smart phone will have. Step sensors are quite common in our everyday life, and in fact, it has been used in some game design. The most famous implementation is the Pokémon Go in which he Pokémon egg can be hatched by player walking in real world. There can be more ways of using steps, in the example here, new stages of the game need to be unlocked by the number of steps that player walk.

Sleeping pattern can also monitored. There are some apps that gives sleeping data by analyzing the sound when people make during sleep, more accurate way of doing so is by using wearable devices, which can analyze sleeping pattern by sensing heart rate. In the example here, the sleeping quality is transformed into heals for the game character, the better the player sleep, the more energetic the game character will be in the next day.

In summary, bio connection is a novel feature in exergaming field, which gives playfulness motivation and at the same time guides the player to exercise correctly and efficiently. With the great number of everyday-life bio data to be integrated, it is possible that it become a behavior-changing feature in exergaming.

Figure 3.7   steps connection
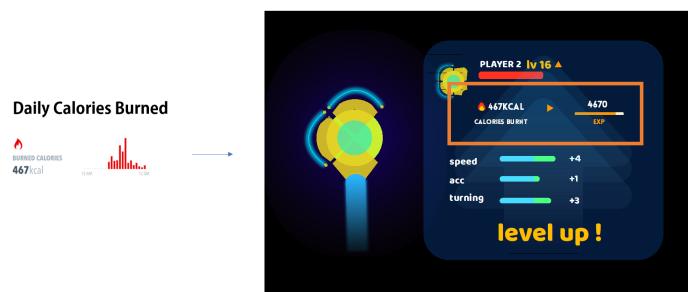
Figure 3.8   calories connection

Figure 3.9 sleep quality connection

Chapter 4

Proof of Concept

4.1. introduction

In the last chapter, sportification methodology and bio connection were introduced as the two main concepts in designing the future exergames, which were later implemented in the prototypes. Two exergames were created as prototypes during this project. The first prototype mainly focuses on putting the sportification method into practice. After testing and evaluation on the advantages and limitations, we went on one step further by creating the second prototype, which integrates both concepts and has major improvements in many aspects. In this chapter, the development process of the first prototype will be introduced.

The first prototype is an exergame called Space Bouncer that focuses on strength training. By using EMG arm bands, the movement of lifting dumbbells are turned into commands to control character movement in an engaging 2d platformer game that designed for a full bicep workout.

The project started in April 2019, which was later named Kinix, an altered word from Greek word " κ ν η σ η ", meaning movement. A team of 4 people was formed including Marcelo Padovani, Hao Shuang, Felipe A. Guarin, and me. My responsibility in the team is design, for the first prototype specifically, the parts that I contributed to are the game mechanism design, game concept and art, game UI/UX design, product design for the hardware.

4.2. The reference game

Following the sportification methodology, the first steps of designing the exergame is by looking at existing games that has a good mechanism. Since this was the

first game, considering limits on budget and time, we decided to start with a small game that does not have a too complex game system and with little game controls. After researching and playing we focused on a game that released on Nintendo Switch called Jumping Joe and Friends.

Jumping Joe and Friends is a 2d platformer party game that has both single player and multiplayer mode. The gameplay is rather straight forward, player need to control the character to jump left or right to the higher platform in a vertical scrolling stage by pressing A or B button. At the bottom of the stage there is a moving lava, which will be chasing behind the player and it will kill the player if he or she jumps too slowly. But jumping fast is not without a challenge, firstly, because the character can only land on one of the platforms above, if the player jump to a direction where there is no platform to land, the character will die instantly, which challenges the reaction for the player when jumps get quite fast. Secondly, there are many traps on the platforms, for example, there are different kinds of spikes, some are stationary, and others are moving, which instantly kills the player. Thirdly, the game gets harder when as the player reaches higher stage, the longer the player plays the harder to survive. Fourthly, all the traps and platforms are generative, which means each time the player will have different stages that are completely randomized, therefore the player cannot get fast just by playing over and over again and form muscle memory, instead, the player can only rely on temporary reaction.

There are also bonus items on the platforms, such as bomb that can clear all enemies on the screen, and rocket, which enables the player fly for a short period of time, and hat, which can protect the player from one death. Coins and gems can also be granted during the game which are used to unlock new characters and skins. Characters in this game not only have different appearance but also have different skills. Each character has one unique passive skill, for example, one character will have a bonus hat, which grant the character with one more life at the beginning of the game.

During playing of the game we found out that the fun part of the game is making quick decision, the player needs to foresee the platforms above him and plan the best route that has less traps and more good items, then execute the plan as fast as he can. Making decisions, acting fast and meanwhile taking the risk is

why the game is exciting. Later our game was designed and developed based on this game, which was named Space Bouncer.

(https://www.nintendo.com/games/detail/jumping-joe-and-friends-switch/)

Figure 4.1 Jumping Joe and Friends

4.3. Movement

To convert the reference game into an exergame, we need to replace the game controls with physical movements, which in this game are only jumping left and right. We took a look at all the current exergames and we found that most exergames are aerobic exercise, there are little games that focus on strength training, so we decided to give it a try.

Lifting dumbbells is one of the most common strength training which is also one of the oldest training which has a history of more than 2000 years. In ancient Greece, Spartan youth had been doing strength training with different weights such as animals, stones. The way people do it remains almost unchanged since then, we just changed from lifting stones to lifting dumbbells. Also just like many other strength trainings, lifting dumbbells is extremely repetitive, which we thought it is a great opportunity to add entertainment to it by connecting this movement to a game. We finally decided on replacing the left and right jumping

29

movement in game with lifting dumbbells with left arm and right arm, which is called bicep curl.

4.4. game mechanism redesign

Redesigning the game mechanism is the most important part in the sportification pipeline, it determines how much the original game elements are remained and how effective the exercise will be. The goal is to delivery an engaging exergame within the constraints of sports science. If the original game dynamics conflicts with the sports science, there will be compromises to make.

For this exercise specifically, one need to do 4 sets of bicep curl, each set contains 12 times of lifting on both arms. The process must be slow enough to maintain the muscle tension and there can be a short rest between each set.

Based on the rules of bicep curl, the first change that was made on the original game mechanism was the overall game structure. In Jumping Joe and Friends, the game has no ending, the player will be continue playing unless the character dies, which does not fit with the sports science. Therefore, the game mode was changed from an endless survival mode to stage-based mode. The idea is that the stages are the sets, there are 4 stages in the game, with a 30 seconds interval between them, so when they clear all stages, they finished a complete bicep training with proper resting time. In order to make sure that the player lifted enough times on both arms, the trigger to end one stage is number of lifting, which is when both arms lift 12 times or more. One interesting feature in the game is that, although the player do not have to follow a fixed pattern of lifting, (e.g. lift one arm then the other until the end), they will always end one stage with a balanced number for each arms. This is because of the platform design itself. Each level has maximum of four columns of platforms, if the player is on the very left platform, the maximum number of continuous right lifting is 3, because, one more right jump will make the character fall from map which kills the character, therefore when one arm reaches 12, the possible number of the other arm is between 12-15. This mechanism allows the player to freely choose which arm to lift and at the same time ensure both arms get adequate and appropriate exercise. To sum up, by redesigning the game structure and platforms, the game makes the player finish

a full bicep training with 4 sets of bicep curl by finishing all stages.

The second part of the redesign will be focusing on the core gameplay. in the reference game, there are two main points about the core gameplay. Firstly, unlike some other parkour games or rhythm games where the player can only passively hit the notes or avoid obstacles, this game does not force the player to do a certain movement at certain points, instead, it allows the player to have a decision-making process, and each decision will influence the next one, which will make a huge difference if the player gets all optimal decisions. This will also fundamentally change the experience of the exercise. Normally strength training is extremely repetitive, even though a few exergames tried to bring some entertainment to strength training, they end up being the same way of doing the movement but with a visual guidance, like in Wii fit there are instructors and some indication bar to guide the player when to do the movement. Some games did better than Wii fit by replacing those indication bar by obstacles or monsters that player need to do the movement to avoid, which added a bit of immersion, but the players are still passive, they can only do the movement when the game ask them to do, Whereas in Space Bouncer, player are doing each dumbbell lifting based on their own decision, and each move matters. This mechanism allows the player to actively control the game rather than the game controls the player. Therefore, this part of the core gameplay is absolutely critical, and we decided to have it remained.

Figure 4.2 Decision making process

The second main point of the original gameplay is the fast pacing, especially in the multiplayer mode, the player who are left behind too much will be killed, therefore player needs to jump very fast but the same time it increases the risk of bumping into enemies or traps. This mechanism, together with its fast music and vivid animation, create an exciting experience for the game. However, this fast-pace gameplay conflicts with the sports science of bicep curl. Doing the dumbbell lifting too fast might result in getting injured or not moving with the correct muscle, therefore speed should not be encouraged in the exergame. We decided to remove the fast pace feature in the game, and instead of speed, we want to strengthen the decision-making feature to make it a strategy-based game rather than action-based game.

To achieve that, new features need to be designed, because in the reference game the strategic feature is too simple to support the gameplay on its own. The most important feature that was innovated in space bouncer is called Super Jump. In space bouncer, there are two types of platform, one is blue, the other is red. When the player is on a same color platform for 3 times in a row, his next jump will be a super jump, which will give the character a power-up to jump 5 levels higher which also gives 5 bonus scores to the player. Super Jump is designed to make player think and plan their route before making each decision. The score system is also redesigned based on the purpose of encouraging decision making rather than speed and super jump feature is at the core of the score system design. Now each successful jump counts one score, Super jump counts 5 score, if the player dies, he can still continue the game (because we want player to finish the 4 stages without interruption), but he will lose all scores. Sometimes the player needs to think whether it is worthy to go for a super jump but with more traps on the route or go with a less risky route but with no super jump bonus. Therefore, the super jump is a crucial way of getting high score, but at the same time having high risk of losing all score. Apart from super jump, we also implemented new traps, items, and bonus to further strengthen the strategic aspect of the game, making decisions matter much more.

In summary, in order to transform the game into an engaging and efficient

Figure 4.3 game features

exergame, the following decisions are made in redesigning the game mechanism. Firstly, reconstructed the game structure and game mode to make it fit the exercise routine. Second, kept the core gameplay of decision making which brought unique experience in strength training exergames. Thirdly, shifted the game from an action-based game to a strategic-based game to make it fit with the exercise tempo. Fourthly, strengthened the strategic aspect of the game by implementing Super Jump features and new score system.

4.5. Hardware

Following the sportification pipeline, while the game was been redesigned and programmed, the hardware development was also carried on in parallel.

In the early stage of choosing the hardware, we thought about normal options such as implementing accelerometer sensors on dumbbells or using Kinect to capture motion, but finally we decided to use electromyography sensors, also known as EMG. EMG sensors can detect the muscle activity by sensing the electric signal that running in the muscle when muscle is activated. The reason why we chose EMG is because we wanted to implement the Bio connection concept to this game. The bio connection concept is not only used to control the game, because other sensors can do it without bio information, but also to reflect body change in the form of responsive gameplay. For example, in this game particularly, we wanted to understand muscle strength, muscle fatigue, and postures by reading the muscle

data, and reflects those change in the gameplay. However due to various reasons this attempt was not successful which will be mentioned in later chapter when we tested the sensors.

The design of the whole system is as the picture showing below. The two EMG sensors will be attached to both biceps, and they are controlled by an Arduino Nano that sends data wirelessly through a HCO5 Bluetooth module to an Arduino MEGA connected to a laptop, which runs Space Bouncer.
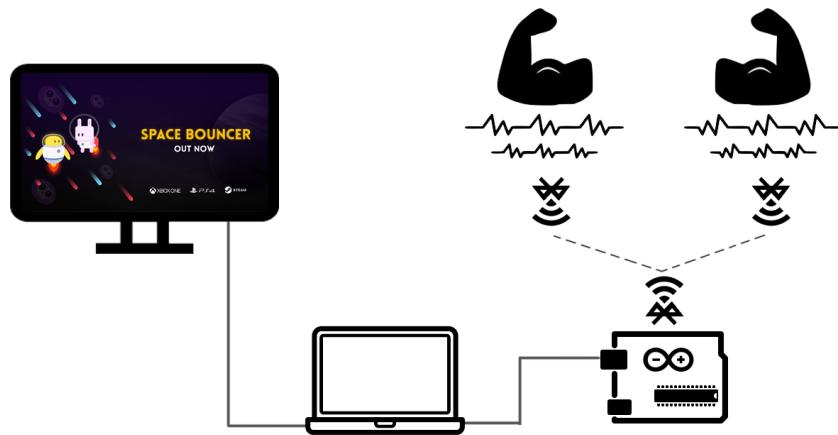
Figure 4.4 diagram of the system

This system enables players to trigger the left and right jump in Space Bouncer by setting up threshold of electricity. The following picture shows the first version of hardware:

The design of circuit was done by Hao Shuang, the coding part was done by Marcelo Padovani. My responsibilities of the hardware part were to design the layout of all these components and fit them in a more good-looking shell and make it a usable product for players while considering ergonomics and comfortability.

The first design was quite simple, I designed a box which can fit all components inside leaving only the wires. The box was then 3d printed and connected with an elastic armband, which can adjust the tightness by using Velcro.
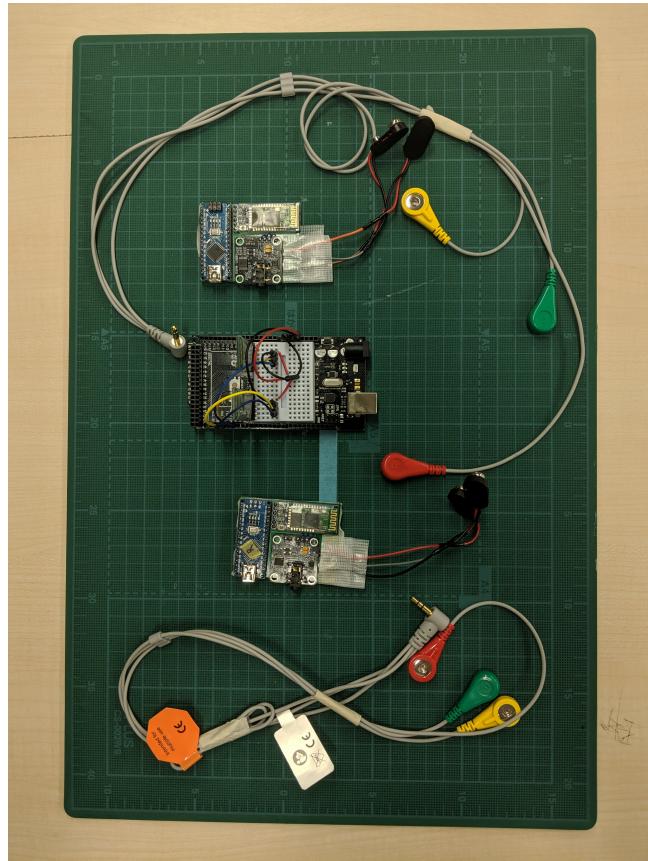
Figure 4.5 hardware v1

However, the whole system was still quite big and messy, the box was not well connected, and it causes interference when lifting the dumbbell to higher angle. The biggest problem is that there needs to have 3 gel pads that extents out from the box and attach to skin which make the whole setup complicated. In addition, the gel pads become less sticky when the player sweats which often leads to the gel pads falling off. To solve these problems, we later updated the hardware design with a smaller Arduino, new EMG sensors that does not need gel pads with extended wires, and better designed chips. Correspondingly, I updated the product design of all the components by sewing them into an armband, then sewed another layer of fabric to cover all wires while leaving the space to change

Figure 4.6 arm band

batteries and control the switch. As a result of the new design, the overall size
of the hardware was able to be reduced significantly and it also minimizes the
influence of the hardware during exercise. Most importantly, the whole setup
become much more plug-and-play. Without having to stick 3 gel pads in the
right position on skin, which normally requires 2 more people to operate, the new
hardware enables the player to wear it by his/her own, just like wearing a normal
armband.
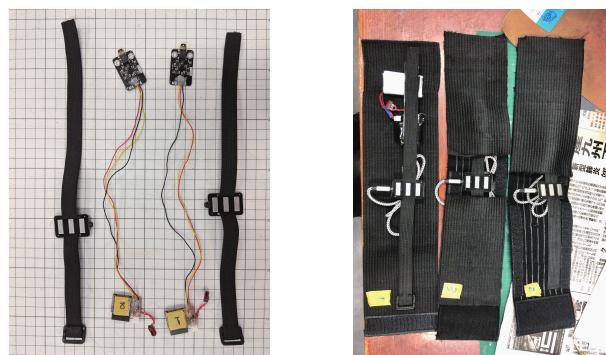
Figure 4.7 hardware v2

4.6. game art and UI/UX design

Although this prototype mainly focuses on implementing the new method of designing exergame, we do believe good arts and design will contribute to the immersion and engagement while playing the game, which is one of the most important parts of our goal.

I was responsible for designing all game arts, game background settings and UI/UX. I started design the game art by writing a background story. Although the game is not a story driven game and it does not have any narratives, creating a world setting is always a good way to start creating characters. The story goes as follows:

In a faraway galaxy, the planet Boncerium lives the most brave and skilled group of space explorers: Qi Qi, Martian, Kuri and Baotsu. Qi Qi is the commander of the LEAP3000 the lead spaceship used to gather the quantum gems, the main source of energy of the planet Boncerium. Qi Qi and his crew were attacked by Warudemon, the evil leader of the Dark empire, who's objective is to vanish all bouncers of the universe. In the attack Martian, Kuri and Baotsu were kidnaped and taken to different parts of the universe, Qi Qi was able to escape and now his life's mission is to bounce through the universe finding and saving his friends.

According to the story, the game happens in space, containing 4 main characters and a group of villains. Then I started with character design. To make this game appeal to a large group of people, I chose to use a cute cartoonish style but with clean and modern aesthetics. The first few concepts are rough sketches and were then regulated and vectorized in illustrator in order to get clean and restrained lines.

4 characters were designed with unique characteristics and skills. All of them are by design, playable in the game, although eventually only the character Qi Qi was implemented. In fact, super jump is only Qi Qi's special skill, if all characters are implemented in the game, they would trigger different skills when they have the color combo, and each skill is also designed to fit the character's personality. For example, the rabbit character Kuri is designed to be a peaceful and lovely character, so she does not have any aggressive skills, instead, her special skill is to make enemy become friend. On the other hand, Baotsu, whose appearance is a big dinosaur, has a strong attack skill that can clear all enemies on screen

by spitting fire if he is on a red x3 combo. When designing the villain, I also considered the overall style and the goal to make it appeal to more people, I tried to make the villains a likable character too. To show they are "bad guys" I used elements like skull but adding cute eyes to make it not scary. Also, I designed the spaceship of the villains, which resembles their appearance too. This add a bit humor to the villain design, now they are like cute space monkeys rather than scary bad guys.

Backgrounds are also specially designed for the stages. Instead of using only space or star elements, which could be boring if four stages look pretty similar, the background of the game goes from a scene of city, and then to sky and finally to space, each stage has its unique scenery. In addition, Parallax Scrolling technique was applied, which means all of the background elements are divided into 3 different layers which moves at a different speed while camera scrolling. This make the background look more real and creates a 3d illusion.

Eventually after finishing all the art, I created a key visual of the game, including all characters, the villains, space background and a logo.

Figure 4.8 key visual

The UI/UX design of the game follows the idea of creating immersive experience. In order to achieve this, we firstly decided to make the game in 4K resolution with a vertical video output which will have the best seamless visual impact since the game is a vertical scrolling game. Secondly, I avoided using too much cold numbers and instructional text and tried to use more visualized and gamified language.

38

One example is the design of Heads-Up Display (HUD). In this interface, it tells the play the number of lifting for each arm and their total score. But instead of just showing the numbers, they are designed to be like a control panel on a spaceship. The numbers of lifting (jump) are shown in the circular progress bar, the color of the bar changes with the number from green to red and eventually become a "overheat" icon when the player finishes one stage, at the same time the score display will also turn into a screen with "cooling" text. This is to resemble a spaceship engine overheat state, which is much more interesting than saying "session one finished, now rest for 30 seconds". The whole HUD design only takes a small area at the bottom of the frame giving most space for the contents, thus created immersive experience.

While minimizing the use of number during the game, it is still important for the player know the data, therefore we put a stats screen at the end of the game showing both bio data such as calories and lifting numbers and in-game stats such as scores and collected coins.

Figure 4.9 HUD

Between each stage there is 30 seconds resting time. I thought about how UI could guide the play to have a rest and meanwhile not letting the player lose the immersion of the game. Therefore, instead of showing texts of resting and a countdown, I created a popup window with an animation of one of the in-game characters putting down the dumbbell and resting. To make the resting time less boring, I then created 16 different picture using in-game elements, each one can give information such as small tips, game rules, character introduction, game background settings, etc. random one will appear for every 5 second during the resting time. This UI design between each stage was designed to give guidance for the player while keep them interested.

Apart from in-game display, I also designed the menu parts including main menu and a page for character selection and unlock features. By design, the default character is the Robot QiQi, other characters need to be unlocked with in-game currency which can be collected during each game.


Figure 4.10 unlock feature

40

4.7. Preliminary user test

4.7.1 Setup

On July 23rd, we did a preliminary user test, which was carried out before the hardware was designed. The main goal of the test is to get some insights on the game design by testing the level of engagement and entertainment.
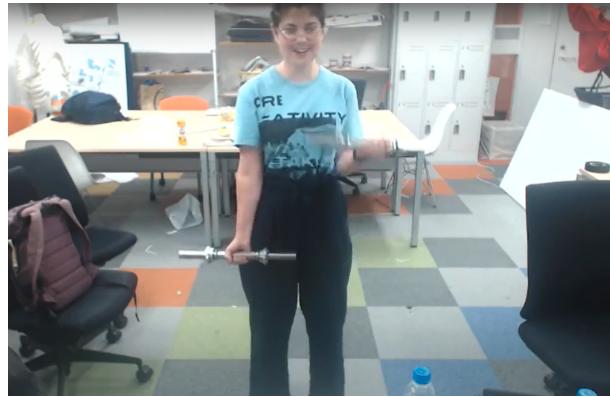
Figure 4.11 Preliminary user test

The user test consists of 4 parts. In the first part, participant will be given time to read and sign a Consent Waiver. Then in the second part, we will read a script which introduces the purpose of the research, the game background, and rules. The third part is participants playing the game, each participant will be asked to choose dumbbells that they feel comfortable with and finish all 4 game stages. The last part will be filling a survey and ask some open questions.

Since we had not created the hardware at this time, the game control was done in an alternative way. During the game, one of our team members controlled the character movement remotely. We used an app called TouchOSC, a modular OSC and MIDI control surface for Android which supports sending and receiving messages over Wi-Fi. While participants playing, the operator was sitting behind him/her, looking at the arm movement of the participants, then press the corresponding button on the TouchOSC app to control character jumping. There was no perceptible latency in the transmission of signals, and we practiced a few times

to make sure the accuracy and responsiveness of the manual control is optimized to a point that the player would not notice.

4.7.2 testing result and analysis

4 participants, 2 males and 2 females, aged from 26-35, took the questionnaire, which was designed based on standard gameplay test. The questionnaire consists of 28 questions in total, which were grouped into 7 aspects, including accomplishment, challenging, competition, sense of guidance, immersion, playfulness and sharing. The Likert scale for each question is from 1 to 5, scaling from "not at all" to "extremely". In the following part, some result highlights will be shown.
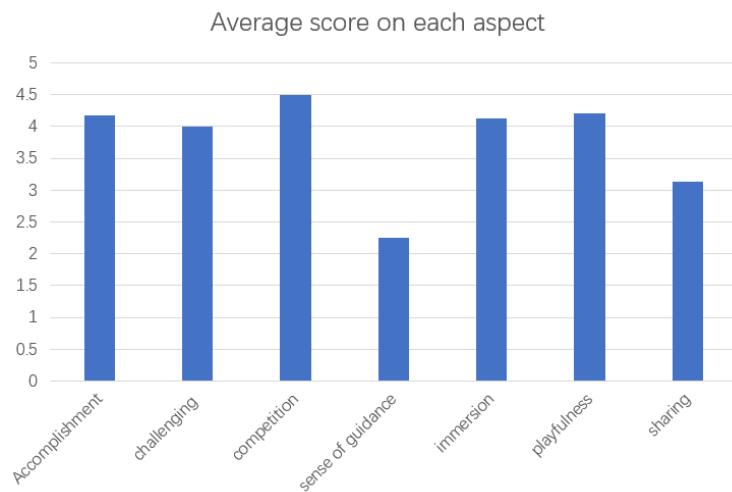
Figure 4.12 average socre on each aspect

In the above figure, the average score for each aspects of the game are shown. Overall, the game was highly rated in regard to accomplishment, challenging, competition, immersion, and playfulness, which are all above 4 score out of 5, and less rated on sense of guidance and sharing, which were rated below or around 3. It indicates that players were generally satisfied with the gameplay and were motivated and engaged with the game.

42

The competition part was rated the highest score. Although the game does not have a real-time multiplayer mode, it will show the final score at the end of the game, and all the participants could see each other's score, which made them want to compete. The two questions under the aspect of competition are "Inspires me to compete" and "makes me want to be the best", which were all rated more than 4 score for each participant. In the open question, participants also expressed that they wish they could play against each other in real time which will make it more competitive and fun.

Participants also liked the immersion of the game. The following figure shows the scores for "Causes me to stop noticing when I get tired"

Figure 4.13 cause me to stop noticing when i'm tired

Making people forget about doing exercise and immerse into the gameplay is one of the most important goals of creating the game with the new method, and it was rated 4.25 on average, which indicates the game provides an unique and immersive exergame experience that people enjoyed. In the open questions, player's answers towards the question "What did you like about the game?" also justified the argument with one participant saying "Fun and promotes people to do more exercise without actually noticing they did a lot.", and "It was fun! And definitely was a good way to get me to work out. I need to be tricked into doing so."
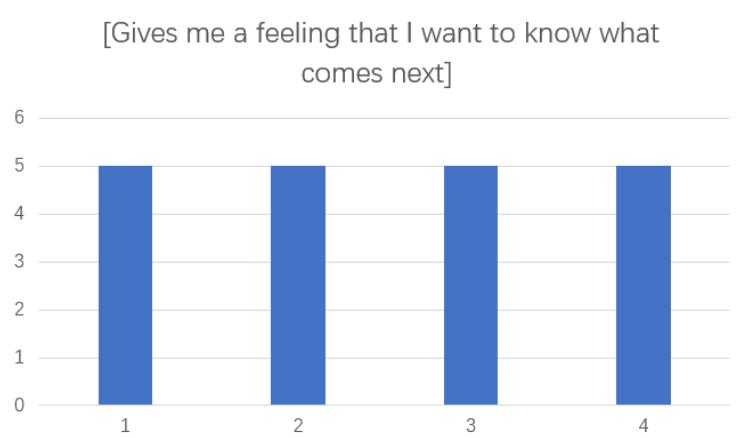
Figure 4.14 gives me a feeling that i want to know what comes next

In the subject of "Gives me a feeling that I want to know what comes next" which is under playfulness aspect, all participants gave 5 score. One player said in the open question: "it was funky, I loved the purple farts. apart from that, it's simple enough bit addictive, I think the aesthetics, the back story and the gameplay made me want to play." It shows that the gameplay, arts, background story and stage design appeal to players' curiosity, as the game progress, new features appears which make them want to continue playing.

However, in the aspect of "sense of guidance", participants generally gave low score. As the above two figure shows, the player felt they are not directed, and there was not enough feedback. The open question of "What new features would you add to this game?" also reflects the concerns of lack of guidance. Participants gave ideas such as adding more visual feedback for each movement, adding a instructor feature that can encourage player, adding negative feedback when players want to play more than what they could, adding posture correction. We can see the problem of lacking feedback are from 2 aspects, one is about the gameplay. the game lacks visual and sound feedback for the character movement, and it also lacks guidance of how to play the game. Like in the open question of "what didn't you like about the game?", One participant said they did not

[Gives me a sense of being directed]
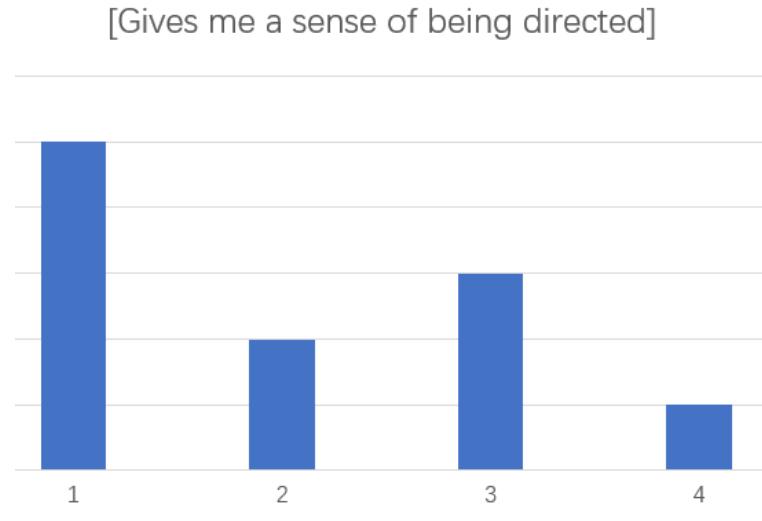
Figure 4.15 give me a sense of been directed

understand the function of some items and skills at the first place.

The second aspect of lacking feedback is that the game did not instruct the exercise enough. The game design enables the players to finish a full bicep workout with 4 sets, without noticing they are exercising, in that sense the initial goal of the game design was achieved, however, this only secured the quantity of the training, but not the quality. Through our observation we found that players are too immersed into playing the game that they completely forgot about posture, which is extremely important in the strength training. They often do a rough lifting to match the timing of jumping without doing the complete move. Sometimes when they are extremely tired but still want to go for the jump, they will use both arm and back muscles to lift the dumbbells which is a wrong posture. Doing dumbbell lifting in a wrong posture will not only lead to inefficiency of workout but will also cause potential injuries. In addition, we found that player tend to go faster than they should be. Although the game was designed to focus on strategy rather than speed, some players would go for another jump right after the character lands on the next platform.

In summary, the results of the game test indicate that the game design succeeded

in turning the exercise into an immersive, playful, and challenging game but lacks feedback both for the gameplay and exercise. we concluded that this version of game.

4.8. Iteration

4.8.1 gameplay feedback upgrade

After the user test, we realized that the game now needs some improvements on the guidance for the gameplay and for the exercise.

The first thing we added is a tutorial, we found during the test, some players did not understand the function of certain items and the super jump feature even if we explained the rules at the beginning. Therefore, we added several screens before entering the game, each one showing an animation of the item effect, so that the player can directly see what will happen if the effect is triggered. All these introductions are in visualized and animated forms which resemble exactly what will happen in the game.

To further guide the player through the game, we also added or strengthened the visual effects. For example, the trap platform design changed from a platform with a still lightning icon to a platform with electricity current moving animation, which clearly indicates the platform is dangerous and the player should avoid. More animations were added on the characters too, such as getting damage, dying, jumping, super jump. Meanwhile, the sound design was also upgraded by Danny Hynds, who created a main theme soundtrack and sound FX for all animations. All sound FX are at the same key with the main theme so that it created a unified musical landscape that belongs to the Space Bouncer universe. All of these audiovisual feedback upgrades will increase the sense of guidance by improving the responsiveness of players' moves and giving clearer information on all game elements.

During the observation of the preliminary test, we observed that some people tend to lift faster than they should, we decided to solve that problem by changing one visual feedback related to character movement. We changed the animation speed of character jumping, to make the jump much slower, and the duration of

the animation is as long as the desired interval between each lifting, therefore the player is not able to do another jump during the animation because the character has not landed on the next platform, this would slow down the player who want to lift the dumbbells too fast. In addition, to make the animation look natural, we created a low gravity condition in Unity to simulate a realistic jump motion, and because the game background is from earth to space, it feels natural to have a low gravity environment.]

4.8.2 Exercise feedback upgrades

On the other hand, we also wanted to add more feedback to the exercise. Our initial thoughts were to use the data that we get from EMG sensors to create a bio feedback that reflects in the gameplay. For example, we thought about calculating the muscle strength using EMG data and connect the muscle strength with character ability. We also thought about understanding the muscle status so that the game can be responsive to muscle activity, which can enable us to detect muscle fatigue or provide posture correction functions. However, during hardware testing, we found out these ideas were not feasible.

The main reason is that EMG data is extremely easy to be interfered by different variables. Since the principle of EMG is detecting the electric current, anything that might change the resistance would cause huge influences to the final data, such as the connection between the sensor and skin, the sweat on the skin, the change of position where it attaches to skin, type of muscle fiber, muscle length, and muscle velocity, etc. In addition, we also observed that the EMG data shows a huge individual differences, and even on the same person, the average number of the data shows significant change in different times mainly due to the difficulty of controlling all the variables. According to a research by Thomas J. Roberts and Annette M. Gabaldón [9], EMG reflects the electrical, not the mechanical, events of a muscle contraction, and any inference of force from EMG must be done cautiously in a strict medical-level measurement, because a number of factors can all influence the relationship between electrical and mechanical activity of a muscle. Therefore, we came to conclusion that, in our situation, it is not feasible to get usable data from EMG to calculate muscle strength and create the bio feedback loop.

The second reason is that a single EMG sensor was not able to tell if the players are using the correct muscle or if they lift the dumbbells to the designated angle. We would need stable and reliable data from most main muscles on the upper body to know this information. In that case we would need an EMG suit to collect data.
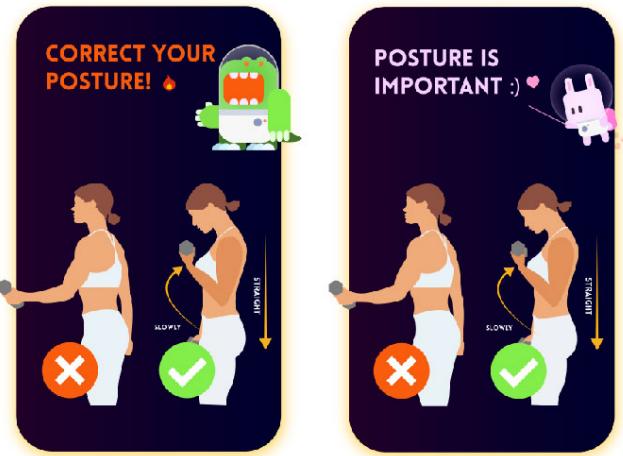
Figure 4.16 posture correction

Although we were not able to use EMG data to create bio feedback, we did make it responsible to the game control by setting up a threshold after calibrating with each player. In order to give more guidance to the exercise, we thought about other ways. Firstly, we added several screens before gameplay tutorials with animations to teach the player the correct movement. Secondly, we designed a popup screen which shows the correct movement. When we observe that the players are doing the posture wrong, we would manually trigger the popup screen to correct their posture. This is to simulate the bio feedback system in a manual way. In order to keep the immersion, the popup screens were specially designed. One of the in-game character will appear on the top right as an instructor to guide

the player, if the screen appears for the first time, it will be Kuri, the cute rabbit character to be the instructor, and if the screen appears for the third time, the instructor on the popup screen will become the dinosaur character Baotsu who are looking angry.

In summary, the new version 1.1 upgraded visual and audio feedback for the game, added gameplay tutorials, exercise instructions and manual posture correction function.

4.9. Exhibitions

4.9.1 Introductions

After the version 1.1 was finished, Space bouncer participated in several exhibitions and showcasing events, including the Super Welfare Expo 2019, 映像のまち かわさき, and Dunlop Sports showcasing. This part will briefly introduce each event.

Kinix team was firstly invited to showcase Space Bouncer in the Super Welfare Expo 2019, which was held in Shibuya, Tokyo on Sep 8th-9th, 2019. The exhibition is a project that started in 2014, aiming at showcasing ideas and designs that fall outside the traditional framework of welfare, and promote equality between different social groups. We setup a booth with a display, posters and 3 sets of dumbbells with different weights. 3 Kinix members were in charge of calibration and hardware setup, and we were also helped by 3 other volunteers who were in charge of queue management and guidance. During the two days of exhibition, around 100 people, including kids, elderly and disabled people, experienced Space Bouncer, and it was well received, we observed thee process and asked some of them for opinions. On the second day, the game was also showcased to the Tokyo minister of education.

On November 13, Kinix was invited to an event which was held in Dunlop Sports Club Gym in Chiba, which we used as an experimental field. This was a part of international Sports-Innovation-Network (SINN-I), which is a front-running network stimulating and creating innovations in the field of Health Style (physical activity, sports & health) with the core focus of bringing more joy of movement

into the world. During the event we showcased Space Bouncer with partners from Dunlop gym, Jymmin, and Innovationsmanufaktur. We shared ideas and discussed the potential and limitations of the game with sports science experts and fitness industry leaders.

On Feb 23rd, 2020, Kinix participated in an exhibition called 映像のまちかわさき where we showcased Space Bouncer with the upgraded hardware and vertical full screen display. More than 50 people, with a wide range of age group, experienced Space Bouncer on the exhibition day.

Figure 4.17 exhibitions

4.9.2 Feedback and analysis

During the two exhibitions, we observed people 's reactions on a large quantity and we also asked some of them for opinions, from what we have seen and heard we have the following findings.

Firstly, people generally found the game engaging and immersive, especially kids, teenagers, and elderly. Almost all players wanted to finish the all 4 stages of the game even if the physical exercise was challenging for them. When getting items, triggering super jump, and dodging enemies, players reacted to be excited and happy. When we asked some of them about the general experience, many answered "fun", "engaging" and "makes me forget the physical exercise."

Secondly, people learned the game through playing. We noticed that many players did not understand the right way to play at first, for example, many of

them still tried to be fast, or constantly died by bumping into enemies in the first stage, but with all the feedback implemented in the game, they gradually learned how to play the game in later stages. They would slow down the pace and start planning the route with more combo platforms, picking up protective items, waiting for the timing to jump in order to dodge the enemies, they would play more cautiously with patience and strategy, which is exactly how the game was designed to be played. This proved that the new gameplay feedback features worked, it guided the player to play the game in a correct way.

Thirdly, people liked the competitive and social experience and expected more of such experiences from the game. On the exhibition, most people came with friends, partners, or family members. Although the game did not have multiplayer, players did found ways to interact with other people. For example, we often notice people would help, cheer, give advice, give comments, laugh, and shout when they are watching their friends playing and take turns to play the game. In the end, they would compare the final score and pick the winner. In this process both player and spectators are actively engaged with the game. This phenomenon indicates player enjoyed playing the game with friends. The feedback from the players also reflected that idea. The most frequently suggestion for the game is ask if we can add a multiplayer mode which they believe will make the game much more interesting.

Fourthly, the workout efficiency was still not ensured. Although people generally said that they felt they exercised, it was mostly because the quantity of lifting was secured, but the quality was hard to measure. In the last iteration, we added several measurements to address the issues of ineffective exercise, which worked in some cases, but we still observed some people playing the game with wrong postures and pacing.

Fifthly, the EMG sensors has a lot of limitations. During the exhibition, the hardware gave us the most troubles. As mentioned previously, the EMG sensor data can be influences by a great number of factors, which resulted in adding a calibration process for each player. But even after the calibration, because the EMG data magnitude can change significantly during playing because of sweat, the change of sensor position, connections···, the threshold value that we set for each player can become invalid and we had to recalibrate. In addition, it caused

troubles for the setup, the first version of hardware requires 2 other people to operate, and we had to change 6 gel pads for each player. The updated hardware (arm bands), although in principle does not require operators to help wearing it, in practice, we had to help the player wearing because they did not know the correct position to place the electrode on the skin. Also, because the EMG sensor has to be directly attached to skin, it became challenging to wear the arm band for the players in wintertime when people are dressed in heavy coat, sweater, and long sleeve clothes.

In conclusion, after the user tests and exhibitions, the game Space Bouncer was proved to be an engaging and immersive exergame that provides entertainment and motivation for bicep training. The sportification methodology that we used to design the game, was practiced, and proved to be effective. However, due to the limitations of the hardware that we chose, the bio connection feature was failed to be implemented, which was supposed to be a key feature to create more guidance and engagement. In addition, the hardware itself also caused troubles in many other aspects.

4.10. The second prototype

4.10.1 4.10.1 main goal of creating the second prototype

As been analyzed above, the hardware of the first prototype has limitations which resulted in not realizing the bio connection feature and the cause of some other issues. We decided to create another prototype, using the same methodology of game design and implement the bio connection feature. This prototype was also done by Kinix team, my responsibilities in this game are game mechanism design, art direction and UI/UX design.

4.10.2 Reference game

Following the Sportification methodology, the first step is looking for reference games that have good game mechanism. In choosing the reference game, we took considerations of the feedback that we received from Space Bouncer. Since a great number of people expected competitive and social experience, we decided to look

for competitive multiplayer games. After researching and playing, we found one game call paper.io 2, that can be used as the reference.

Paper.io 2 is a popular online multiplayer game. The game rule is extremely simple, players play as a block in the game which need to move and close shapes to form a territory, the goal is to gain as much territory as possible. Stealing another player 's territory is also allowed. One weakness for all players is that they will leave a trial behind them when they are outside their own territory, once any other player touched the trial, the player will be killed. Therefore, players need to be extremely cautious when getting territory, because been bold and get big territory at once will increase the risk of exposing the trial. The game gets extremely competitive when there are many players in the battlegrounds trying to steal territory and kill other players. The game is fast paced too, players die constantly and get back to another game right away.

(https://appolicious.com/paper-io-2-drawing-murder-combined/paperio2/)

Figure 4.18 reference game 2

Although the game is competitive, it is not a hardcore game that requires high level skills for players, instead, it is a light, fast and fun game that was designed for everyone. This is mainly due to the easy-to-understand game rules and the simple game controls. The game does not have any tutorial, not even any text during the game. It drags the player directly into the game, but after dying a few times, most people will understand perfectly how it works. The game control is

simple as well, the only control that the players need to do is to use the mouse to guide the direction. In this way, the game is easy enough for anybody to play, but at the same time, it requires some skills to be a good player. This is a "easy to learn, hard to master" type of game, this type of games often reaches to the biggest audiences, including non-gamers, light gamers, and hardcore gamers, they can all have fun in the games. The best models of this type of games are Nintendo games such as Mario cart, Super Smash Brothers and Splatoon, which has simple game mechanism but deep gameplay. Paper.io 2 still lacks some depth in terms of gameplay, but it won more because of its simplicity.

We decided to use Paper.io 2 as a reference game, to design a competitive multiplayer exergame that is "easy to learn but hard to master".

4.10.3 Exercise and hardware

The next step is to choose the exercise and replace the game control with physical movement. Space Bouncer chose to use bicep curls as the exercise, to show diversity, we decided to choose an aerobic exercise to apply to our new game. After comparison and analysis, we found that cycling is a good choice for the game. We initially planned to replace the direction control with the steering, and the speed with pedaling, so that players can finish all the basic controls in Paper.io 2 by cycling. Later on, we also integrated the heart rate of the player into the game, which will be further explained in the bio connection part.

To achieve all the controls, we need to get the data from pedaling, steering and heartbeat. From our last experiences, developing additional hardware and sensors will potentially cause troubles, therefore, this time we looked for existing products so that we just need to focus on integration and game development.

For the pedaling part, the hardware we found is called smart bike trainer, it is a tool that allows users to put bikes on it and do indoor cycling. Smart trainers get the data from the wheel, including rotation, torque, power, and distance, which can be sent to other devices through blue tooth or Wi-Fi. By using these data, we can calculate the real-time speed of pedaling and apply the speed in the game.

For the steering part, we used one of the most common devices that people normally have, the smart phone. We mounted the phone on the bike handle, and by using the compass sensor inside the phone, we are able to know the angle of

turning and we can send the data to the game so that player can control the direction of the game character by turning the handle. A big advantage of using a compass sensor rather than gyro sensor is that it does not need calibration to align the center coordinates, as long as the phone is placed up straight, the center of the compass will be physically aligned with the central axis of the bike handle. For the heartbeat, we integrate the data from a smart watch brand, called polar which sends real-time data to smartphone.

The whole system integrates with 3 smart devices which are connected to a computer. The smart phone on the handle part works as a data center where we developed an app that can receive all the real-time data from other devices, then sends out all the data including the compass information from itself, to the computer which runs the game. All devices have open API so that it allows our development.
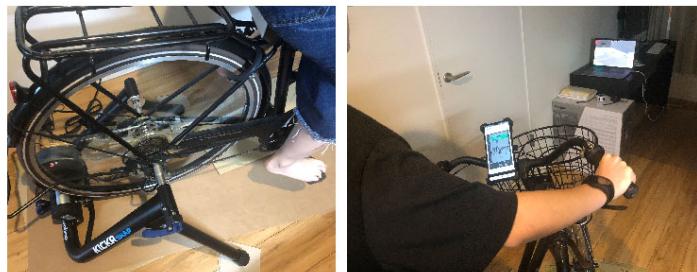
Figure 4.19 hardware system

4.10.4 Game mechanism redesign

After choosing the exercise, the next step is redesigning the game mechanism. The most fundamental change in the exergame is the speed. In Paper.io 2, the speed for all players is the same and constant, in our game, the player would control their speed by pedaling, therefore, the speed of pedaling will become essential to all the moves in the game, including closing shapes, killing, escaping, etc. This puts the pedaling at the core of the game, which is also the core of cycling as an

exercise. the game will become more competitive as speed is added as another competitive elements.

The game structure also needs to be changed fundamentally. In Paper.io 2, there is no end of the game unless player control 100 percent of the map, which is nearly impossible. Normally player constantly dies and restart in another game, it is more about survive than winning. This fast pace game design works perfectly for Paper.io 2, however, for cycling, the fundamental structure is different. Normally, a recommended duration for an indoor cycling session is 30 minutes, minimum is 20 minutes. An easy way is just to put a 30-minute count down for the game and the game ends after the time is up, but that will not be a pleasing experience since the original game was not designed to be played continuously for 30 minutes, players can get bored easily after dying too many times. If the player is in a game that has an endless dying and respawning cycle, with no winning, no team, no structure, they will become aimless after a while. Simply adding a time limits does not solve this problem, it needs to be more structured to be played for longer duration.

After ideation, I found a reference game for redesigning the game structure, which is called Splatoon 2, a Nintendo game released in 2017. Splatoon 2 is a third person shooting game that has a pretty similar basic rule, which is to control the territory in the game. In the regular game mode, players need to splat the map with ink guns, and within a limited time, the team who gets the most territory wins. Although having similar basic rules, Splatoon 2 is much more complex and competitive. Each game will have 8 players, who are divided into 2 teams, each player has unique skills and weapons which has different functionality and effect. This will determine the team roles of each player in the team. The weapons and skills can not only ink the floor, but also deal damage to enemies, therefore, the game involves multiple moves including attack, defense, getting territory, supporting, positioning, fire suppression, etc.

Based on these game mechanics, players developed sophisticated strategies and playstyles. Over the years, the popularity and competitiveness made it became an esports with a large and loyal fan base that is continuously growing. Not only is the game fun to play, it is also fun to watch. Every year there are official

(https://www.theverge.com/2017/7/18/15986256/splatoon-2-nintendo-switch-review)

Figure 4.20 splatoon

and unofficial tournaments that attract millions of people on various streaming platforms. As an esports player myself, I think all the game in this genre has a simple but powerful DNA, which is the beauty of competition. The simplicity in its philosophy, and the depth in game design make esports fascinating. And I think it will be a huge break through if I can combine the exergame with esports elements that inspired by Splatoon 2.

I firstly changed the rule of winning which is the essential part to define esports. Like in Splatoon 2, the game now has a clear rule for winning: the team who gets more territory than the enemy within a limited time period will win the game. At the end of the game, there will be an interface showing the percentage of each team and who wins. This change will solve the problem of aimless game experience.

However, the time is still a problem, a 30-minute game is too long that it reduces the competitiveness. This is because the size of the whole map is limited, but the size of each team's territory is constantly changing, which result in a situation where only the last few minutes are crucial to winning. For example, one team can control 90 percent of the map in the first 25 minute and lose in the last 5 minutes, or vise versa. This discourages and devalues any active moves in the early game, which is likely to lead to a situation where players are passive until the near end of the game. Therefore, the time limit for one game should be reduced. I then

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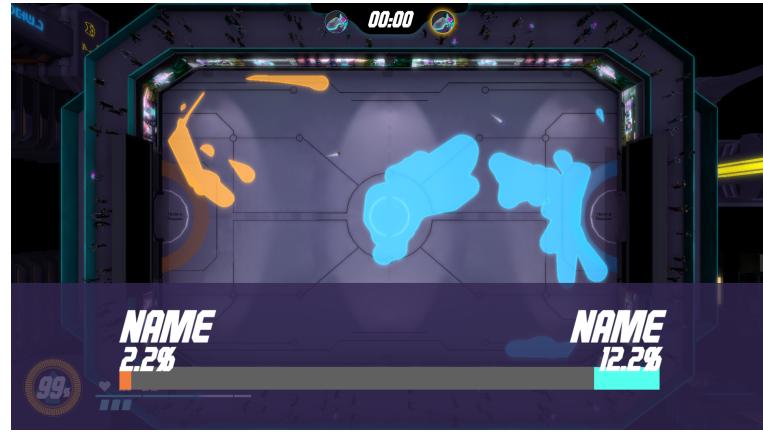
Figure 4.21 game rule

came up with an idea to change the playoff format for each game from a single elimination to a best of three series. Now each game is 10 minutes, team who wins two game will win the series. In the best-of-3 format. the minimum match is 2, maximum is 3, which means the players will either do a minimum cycling session (20 min) or a recommended cycling session (30 minutes). This change improved the game experience and meanwhile made sure the players do full exercise.
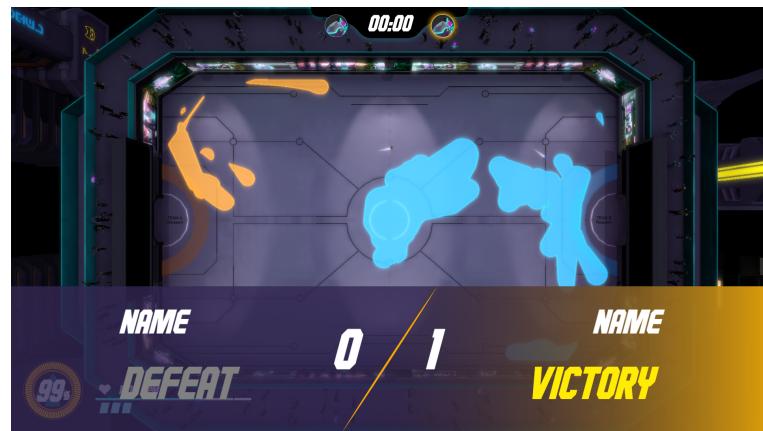
Figure 4.22 game rule2

Next, I decided to make it a team game, which will open up huge space for

more strategies and playstyle. Each game includes 6 players, who are divided into 2 rival teams, the territory is shared and can be summed up by allies. This change makes it a competitive multiplayer game that players need to cooperate with teammate against enemy team.

In addition, I redesigned the map and added some features on the map in order to increase the competitiveness. I firstly created a square shaped arena, with two gates on each side representing the base of two teams. But this design is too simple, any place on the map is equally important. As a result, it decentralized the conflicts and reduces the intensiveness of the fight. Normally in esports, the design of the map often plays a big role in increasing the competitiveness by creating 'conflict' between two teams. For example, in some shooting games such as Battlefield and Call of Duty, there is a game mode called Domination, in which two teams have to control certain spots on the map for a certain period of time to win. The spot is usually designed to be at the middle between the two teams respawn base, and it is designed to be a place where the conflict happens. As a result, usually the center of the fights will be around the spot. Two teams will constantly change their positions between defense and attack, inducing the most intense fight around the spot. Therefore, to further strengthen the competitiveness and conflict, an important feature called "outpost" was added to the exergame. Outpost is a strategic spot in the game which located at the center of the arena. Both teams can control the outpost by including the outpost inside their territory, and it provides special effect (team buff) to the team who is in control. The special effects are 'sinking mud', 'slippery floor', 'double damage' and 'regeneration'.

Each special effect will give the team advantage in the game, for example, the 'Sinking Mud' effect will increase the resistance on the bike trainer for enemy who are invading ally's territory, making it harder to pedal. 'Slippery Floor' effect will speed up players who are on ally's territory. As a result, taking control of the outpost becomes an essential strategy in the game, which increases the conflict around the center of the map. This design will also make sure players are active in the early game, because taking the outpost will build up advantages and make it harder for the enemy to comeback in later games, so two teams must fight for the dominance of the outpost from the beginning of the game. Meanwhile, it

59

Figure 4.23 outpost feature

is also a good opportunity for the team in disadvantage to comeback in late game, if the team catch the outpost and take advantages.

Apart from the outpost effect which provides team buff, I also added items. Items appear on a random place in the arena with a certain frequency, and it will be moving at a certain speed. The player who take item will get a powerup from the it. Unlike outpost effect that act on the whole team, item effect only acts on individual player who takes it and normally only last for 5 seconds. The items include 'health pack', 'health pack EX', 'electric trail' and 'speed boost', which gives effects such as healing, speed up, and lethal trail. The items increase uncertainty to the game, it gives a temporary advantage to players who involved in a local fight with enemy. It also creates the conflict because both two team can get item, they will fight to take items when items appear.

The rule of death should also be reconsidered in our exergame. In Paper.io 2, because of its fast pacing, and "one kill game over" mechanism, player dies very frequently, and no progress will be saved, which can be annoying and distracting in our exergame, considering cycling should be a continuous experience without interference. My initial idea is to use the rules in Splatoon. By adding Health Points (HP), players will not die immediately if their trail is cut, but will lose HP, player dies until HP goes to 0. Also, player will be respawned after a short

period of time to continue the game. This design made sure players will not die as frequent as in Paper.io 2, and because of respawning feature, players will be able to continue the game instead of start over. Although players can be respawned, death punishment is still effective, because when players die, one team will have less players on the battlegrounds which gives enemy more opportunities to steal territory while the dead player is respawning. However, this design still has one problem, while respawning, the player is likely to stop pedaling, which is not desirable in terms of the exercise. Therefore, I added a new feature to the respawn session, the respawning time is now related to the speed of pedaling, the faster players pedal, the faster they respawn. Thus, in order to reduce the negative effect of dying, players will pedal to accelerate the respawning progress to get back to game as soon as possible. Players are encouraged and guided to keep pedaling throughout the whole game by the mechanism itself instead of preaching the player how to exercise. An icon and a progress bar were later added in the interface during the respawning session.

Figure 4.24 death interface

4.10.5 Bio connection

Bio connection is the main reason why we created the second game. We wanted to integrate bio data as a game input and make it a responsive game play, to

increase the playfulness and implement seamless exercise guidance.

In this particular game, we chose to use heartbeat as the bio data to integrate. There are three main reasons why. Firstly, heart rate is one of the most important bio data for aerobic exercise like cycling. It can reflect body status and evaluate the workout efficiency. Normally aerobic exercise uses a certain heart rate as the goal for each workout session. Secondly, there are a great number of reliable smart heartbeat sensors in the market that we can directly integrate to our system without having to create a hardware on our own, which can save us a lot of time and resources. Thirdly, the real-time bio feedback is more apparent to showcase. As mentioned in Chapter 3, there are two kinds of bio connection, real-time bio connection focuses on reflecting dynamic body status in the game experience during a workout session, and the nonreal-time bio connection focuses on reflecting or amplifying long-term small body changes in the game which cannot be experienced the first time when player test it.

By integrating Polar watch, we managed to monitor heart rate during the game. As mentioned in Chapter 3, the bio connection concept is not only about displaying the heart rate number like other exergames do but also turning it into a game element. In this game, we designed a game element for the heart rate, which we called 'Bio ultimate skill'. Bio ultimate skill is a powerful skill for the character that gives the player a speed boost as well as an instant kill ability, the skill needs charging to be able to trigger, and it will last for 10 seconds. The bio connection feature is integrated into the charging process of the skill. Since the goal of aerobic exercise is to raise and maintain the heartbeat to a certain level, we set different levels of charging rate of the ultimate skill according to the real-time heart rate of the player. For example, for a 20 years old person, heart rate between 110-130 BPM is considered as light exercise, from 130-150 is moderate exercise, and from 150-170 is vigorous exercise. The charge rate of the ultimate skill increases as the heart rate increases, we set the standard charge rate as x, which means 1 minute to fully charge the ultimate skill. When the player's heart rate is in the light exercise range, the charge rate is 0.25x, when it is within in the moderate exercise range, the charge rate increases to 0.5x, when the player reaches the vigorous exercise zone, it will charges the skill in the standard charge rate which is x. In addition, the evaluation for exercise level is different for each player according to

their age. As shown in the chart below, as the age increases, the requirement for the heart rate for each level of exercise decreases. This feature was later integrated into our game, by enabling the player to input their age, the algorithm for the ultimate charging rate becomes adaptive to their age.

(http://heartratezone.com/heart-rate-calculator/

Figure 4.25 heart rate zone

In terms of the gameplay, the bio ultimate skill is the most powerful skill in the game, which can be used both aggressively and defensively. It speeds up the player, giving instant kill ability and immunity to any negative effect for 10 seconds. If player trigger the ultimate skill in the right timing, it can even kill all enemy on the battleground, which creates a huge advantage to the team. It can also be used as a strategy to attack or protect the outpost or gaining territory in late game to comeback.

Therefore, the Bio ultimate skill is essential to winning, more frequent use of the ultimate skill enables the team to create advantages and snowball. As a result, the charging rate becomes an important game element, which is causally linked to the real-time heart rate. Unlike some other exergames or training programs which only show the numbers and preach the player what to do, this design favors

the players who are exercising more effectively and creates positive feedback to their effort in the forms of responsive and engaging game experience. In this case, players' behaviors are not guided by cold numbers, instructions, or passive rewards, but drove by the desire of winning, which is the core concept of e-sports.

Additionally, we also connect the heart rate to the visual effect of the characters. As showing below, all the glowing parts on the character, as well as the circle below the character will blink as the same frequency as the real-time heart rate, creating a visual feedback on the bio data.

Figure 4.26 visual effect on heart rate

4.11. Testing

4.11.1 internal testing

On June 3rd, we did the first test of the hardware system and the game within our team. Because before that day, all of our gameplay test was on PC, controlling the game by keyboard. Therefore, the first goal was to test the system, including connections, the latency in game control and accuracy of speed controls. The second goal was to test the gameplay and revise game parameters.

As for the game controls, generally we found the connection is working and stable. The turning has a latency but not as much to affect the gameplay. However,

due to the way that the speed was calculated, the speed does not feel responsive to acceleration. The reason is because there were only 3 speed values, which is not sensitive enough to the speed change.

Figure 4.27 internal testing

As regard to gameplay testing, we designed an adjustment menu interface in this beta version, which consists of different game parameters that visualized like a fader so that we can directly change any parameters in the game by simply dragging the fader. The game parameters include basic speed, arena size, items, enemy, camera settings, etc. We tested several rounds and decided on changing some of the parameters.

4.11.2 User test

After applying new game parameters and improving speed sensitivity, on June 19th we did a second test. This time we were able to not only test within our team but also tested on one person who is not from our team. Unfortunately, due to the COVID-19 influences, we were not able to find more participants.

Figure 4.28 testing game parameters

We set up the system and let the participant played 1min, 5min and 10min game. Before the game we explained the rules and way of controlling. And during the 10min game, we let the player play with all Ais for the first 5 min and one of our team members joined the game using keyboard in the later 5 min.

Because the sample size is too small to give any scientific conclusion especially regarding to the effectiveness of exercise, we decided to do a qualitative interview which mainly focuses on subjective feelings on the gameplay and exercise instead of an objective data-based analyze.

Question 1: Do you consider yourself as a gamer?

No, I don't usually play games, and I rarely play games alone. The games I love most is the games that involves other people, no matter it's social connection, or online competition. But often, I don't stick to a game for long. So, I don't regard myself as a gamer.

Question 2: How do you like about cycling?

Honestly, I don't like cycling at all. I even have some trauma towards cycling due to an accident five years ago. I can't ride a bike on the road.

Question 3: What attracted you the most in the game?

66

What attracted me at first was the atmosphere that the visual and music brought to me. These elements brought me away from the real world. When I started playing the game, all the moving things attracted me. Sometimes I worked hard in order to chase a random moving item. Sometimes I feel nervous to bump into other "players". Sometimes I realized that it's time to reach out to the outpost but I haven't turned around. Also, during the whole process, the bicycle didn't move at all, which made me able to put all my mind on the screen itself but not the world around. One more thing to be mentioned, when I was doing the user test, other people around me were always telling to be care about this enemy, be aware of the trace I left and so on, which gave me a feeling that I were playing with some teammates and added a lot to the playing experience itself.

Question 4: How do you feel about the bio connection feature?

It was cool. I had never paid attention to my heart rate before this user-test. But this time, it's visualized and utilized. My heart rate actually contributed to the avatar I'm controlling which made me felt less boundary between me and the avatar I controlled. That is a part of me, an augmented data of myself and an extension of my body.

Question 5: What do you think about the game controls?

I like it this way. Always I use hands to control the avatar in the game. But this time I tried my feet and my arms. Also, since I'm on a bike, I can't let my avatar to do a right-angle turn directly. I have to admit that it took me a while to get used to this way of controlling. But when I get used to it, it becomes fun. I began to use my mind to think about my following actions I'm going to take in advance. Making such predictions doesn't get me bored.

Question 6: How do you feel about the exercise (physically) ?

I tried all three courses (1min, 5min, 10min). 1min was very easy for me while 10

min is challenging. I can see my heart rate keeps raising during the whole process, but I can't help chasing after some moving blocks. However, I felt I have control over my tiredness since I can change the gear whenever I want.

Question 7: How do you feel about the exergame experience compared to a normal cycling experience?

I felt very safe and immersed when playing the cycling game. When I ride a bike on the road, I have to pay an attention to my balance, the road, the cars, passengers etc. This process makes me feel that I'm just completing a task and always in danger. Also, when riding with friends, we have to shout to communicate and bear the wind. Actually, I have never enjoyed a real cycling experience. But this time is different. This is quite suitable for an indoor girl like to enjoy a game with exercise and communication.

Question 8: What could be improved?

I expect more surprise from this game. For example, more super-power, bonus, new ways of playing etc.

4.11.3 Discussing

From the interview, it can be seen that participant was overall satisfied with the game, with positive feedback on immersion and engagement. It made the player concentrate on the game and forget about reality and physical exhaustion, which is one of the biggest goals of designing the game. In addition, the bio connection was described to be a feature that connects the player to the avatar, making the player feel that her body is actually affecting the game which is also what we were trying to convey through this concept. More importantly, as a non-gamer and somebody who does not like cycling at all, it was a surprise that this exergame had been a good experience for her, which was mainly due to the safeness and entertainment. As for aspects that can be improved, the participant mentioned

Figure 4.29   user test

about more game elements and game modes, which we will look into after polishing the current version.

Chapter 5
Conclusion

5.1. Validation

The purpose of this research is to push the limits of exergame design by practicing the two new concept, Sportification and Bio connection, which provides an instructive methodology to create game-centered, engaging exergames and a refreshing way of using bio data to give motivation and guidance to the players.

Based on the theorical framework, we created two prototypes, and did user tests for both of them to validate the concepts which gave us valuable insights. The games were generally well received, with good feedback on game mechanics, engagement, immersion, and competitiveness which proved that these two concepts are effective in creating entertaining exergames. However, the workout effectiveness still needs further study after implementing full features in the second prototype.

5.2. Limitations

Spirit Overflow was designed to be an online competitive multiplayer game, the competitiveness is at the core of its design. All game features were built upon this competitive mechanism. But so far with the limitations on resources, Spirit Overflow only has single player mode, all the other characters are AI or other players who control with keyboard, which significantly reduces its competitiveness and entertainment. Implementing the full 3 v 3 game experience will hugely influences players behaviors and more study needs to be done based on that situation.

Additionally, there is only one bio connection feature in this game, which is only an experimental step of exploring the new way of using bio metrics. We envision more bio data will be used and transformed into game elements in the future with

various ways in different games.

5.3. Future work

5.3.1 Testify the workout effectiveness

Because the current game can not provide the full game experience, also due to the influences of the COVID-19, the quantitative test of workout effectiveness was not carried out. This user test will be conducted after we are able to create a fair human versus human game experience. The test will be focusing on monitoring and analyzing the heart rate level compared to a normal 30-minute cycling session.

5.3.2 Explore more applications on bio connection feature

Apart from the real-time heart rate bio connection, we also thought about implementing the nonreal-time bio connection. As the concept picture showing below, we plan to use the data stored in the smart trainer and smart watch such as the speed, power and average heart rate and connect the data to game character abilities, each ability has different level and can be upgraded by the bio data. In this way, we are able to reflect long-term body changes into the game and provide customized growth rate for different players according to their body status, which gives additional motivations.

5.3.3 Future of sports and esports

By following the Sportification methodology which use existing good game mechanism as the core and starting point to design exergames, we were able to expand the exergame to some other game genres that the existing exergames had never stepped into. Esports, is one of them. Recent years esports has been growing at an unbelievable speed, with its growing popularity in younger generation, it is just a matter of time when esports exceeds the traditional sports in all respects. Nevertheless, esports lacks the physical exertion which defines sports by its definition. It is also one the biggest criticisms and the reasons why esports still cannot

Figure 5.1 Bio connection

enter Olympic events. But by using the new concepts, we can create exergames that have both esports elements and physical exertion, which might be the future of sports and esports. In the future, we will design more games with physical movements following our concepts. With the birth of this new genre of future esports, we envision in the future, the boundary between esports and sports will eventually vanish, video games and physical movement will be seamlessly combined, which will not be called exergame anymore, because it's a new sport, a new esports and an evolutionary next step for both.
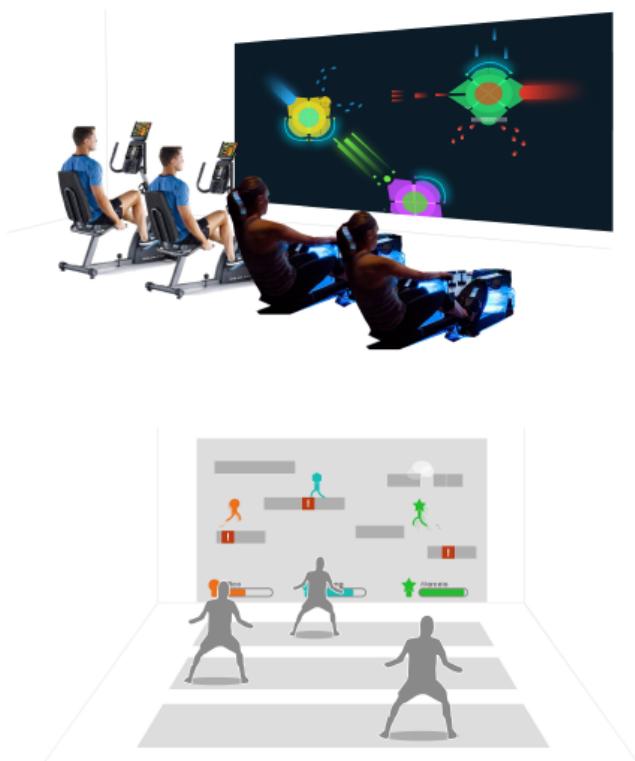
Figure 5.2 future esports

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