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Master's Thesis
Academic Year 2020

Kinix: An Immersive and Adaptive Exergame Set Up to Motivate Physical Activity.

Keio University
Graduate School of Media Design

Felipe Antonio Guarín Angel

A Master's Thesis
submitted to Keio University Graduate School of Media Design
in partial fulfillment of the requirements for the degree of
Master of Media Design

Felipe Antonio Guarín Angel

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Abstract of Master's Thesis of Academic Year 2020

Kinix: An Immersive and Adaptive Exergame Set Up to Motivate Physical Activity.

Category: Design

Summary

For the last decade, exertion games, or video games in which players use their bodies in order to play have become more popular, presenting themselves as an alternative to traditional gyms. The use of Sports science research in the design of such games has led to unveiling the potential of these playful alternatives in order to increase energy expenditure, improve sensor-motor and coordination skills and better the strength and endurance of its users . Today, a wide range of exergames that can be played in a broad range of settings, from public spaces to in-home consoles to play in the comfort of home, but hardly any combines a holistic view of game dynamics, fitness principals and a centralized platform to motivate people to engage in a more active lifestyle.

This is a project aimed to design, develop, and test a connected biofeedback training systems based on a video exercise game to promote motivation and adequate work intensity to improve health. By sportifying a video game,including biofeedback and creating a platform to track progress our design creates an immersive and holistic exercise experience that meets the psychological needs necessary to foster intrinsic motivation to move.

Keywords:

exergame, HCI ,bio metrics, serious games, exertion game, e sports

Keio University Graduate School of Media Design

Felipe Antonio Guarín Angel

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Chapter 1
Introduction

1.1. Overview

According to the World Health Organization, 23(%) of adults and 81(%) of adolescents do not meet the recommendation on physical activity for a healthy life making insufficient physical activity the leading risk factor for non-communicable diseases like heart disease, stroke, obesity, diabetes and breast, and colon cancer [1]. The consequence of a sedentary life is something that ' s affecting nearly 1.4 billion people.

Even though is known that exercising benefit the body, nowadays is becoming more challenging to be motivated to maintain an active and healthy lifestyle. Gymnasiums have become an important part of a modern lifestyle. Nevertheless, gyms are places often related with repetitive movements and stationary exercises that makes the experience boring, hence making the commitment of sticking to a workout program more difficult to achieve.

As a further matter, novice gym goers don ' t have the knowledge nor the experience to judge if a certain exercise is been executed in the right way leading to a higher risk of injure. These factors prevent people from making constant progress.

Gymnasiums have remained unchanged for decades. There are free weights, machines, treadmills, floor-length mirrors, but nothing that inspires the user to keep coming back other than the pleasure of seeing visible results. In this study, we explore the idea of re imagining the gym space as a network of interactive and gamified fitness setups, also known as exergames, that not only engage the user's imagination but also pay careful attention to the body's needs. The exergame designed in this thesis is not just exciting; it responds to the player's bio metrics, skill, and performance. The player gets to enjoy the game so much he or she

forgets they are even exercising.

However, the biggest challenge nowadays is the consequences brought by the novel corona virus (COVID-19). People living under quarantine are living a more sedentary lifestyle, which can increase the health risk. Home-based self exercise initiatives can potentially help improve health and wellness.

We are in the early days heading to a fully connected workout experience that creates personalized and adaptable programs, tracks your performance and motivates you through game dynamics. Wearable technology, IoT and Machine Learning makes this idea of a connected gym much more feasible than ever. in this study I propose a new biofeedback based arcade gym concept aimed to create an entertaining, immersive training experience that strengthens your health.

1.2. Physical Inactivity as a Worldwide problem

One of the most significant public health crises we face today is physical inactivity. It is associated with an augmented risk of various chronic diseases and conditions that can decrease longevity. Modern lifestyle choices have made it challenging to squeeze in a workout session in a busy schedule, despite the widespread knowledge that just a small amount of daily activity can improve general health [2].

To understand what is has been called a pandemic of physical inactivity [3], it is essential to evaluate the current data on physical activity levels and trends. According to a study of Global health data from 122 countries, approximately 88.9(%) of the world population, 31(%) of adults do not meet the minimum required physical activity criteria [4], which means 30 minutes of moderate-intensity activity per day [5].

This value represents the global average, but as stated by the WHO the situation varies depending on the region(Figure 1.1) [6]: 27(%) of the African population is considered inactive, Americas is 43.2(%), Easter Mediterranean is 43.3(%), 34.8(%) for Europe, 17(%) in southeast Asia, and 33.7(%) in the western Pacific region. When gender is examined, men are less inactive, with 27.9(%) and women with 33.7(%) of their population being inactive.

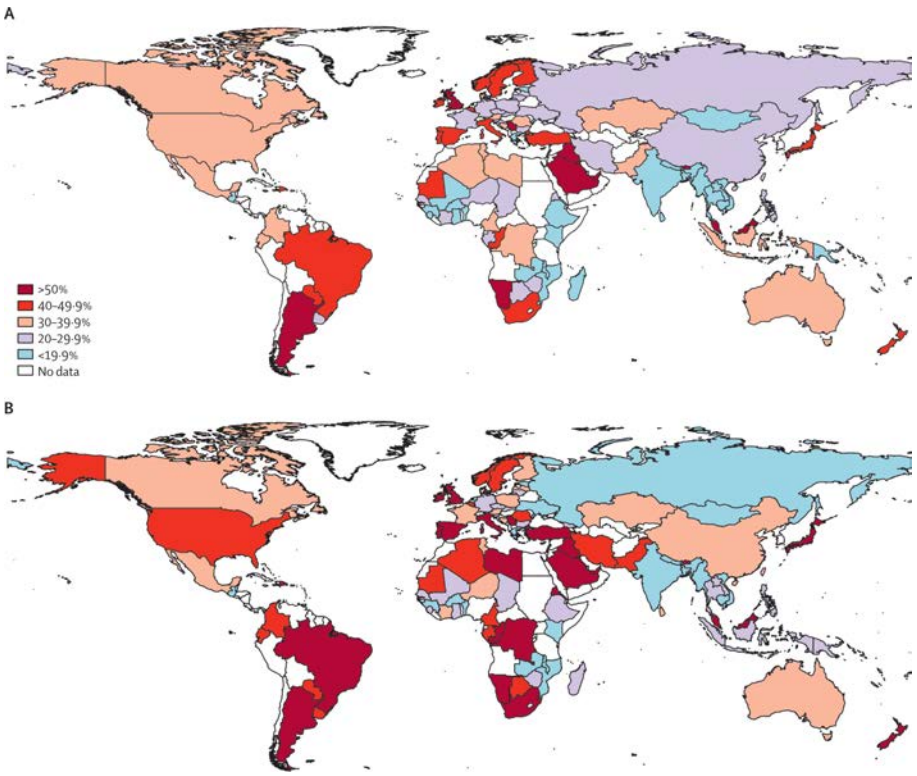


Figure 1.1 Physical inactivity in adults in men (A) and women (B)

Moreover, according to WHO, inactivity levels increase with age (Figure 1.2). By region, the Americas have the most inactive population over 60, and the Asia region has the most active individuals.

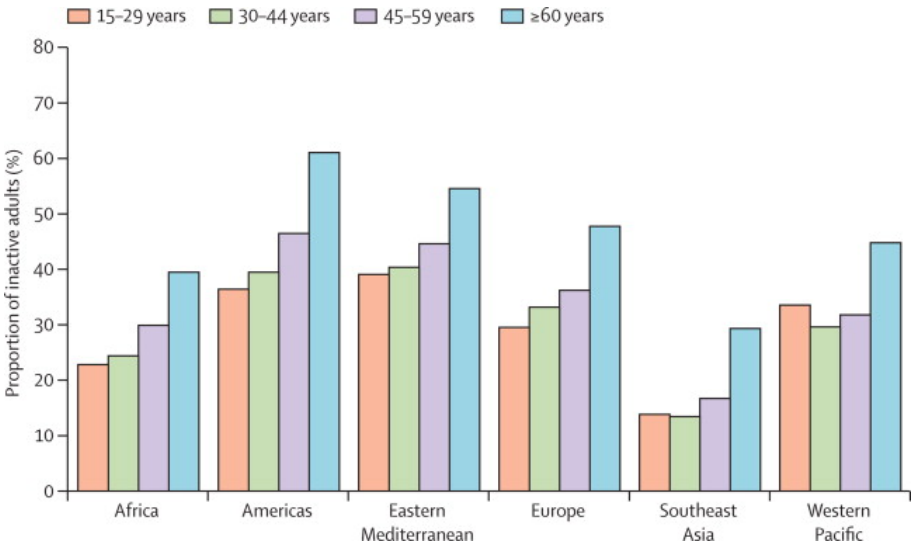


Figure 1.2 Physical inactivity by age and region

Living an inactive life is costing health systems around the world billions of dollars, and roughly 3.2 million deaths per year are associated with this type of lifestyle [7].

Due to the COVID-19 Pandemic and the adoption of lockdown and social distancing measures, sedentarism has risen [8]. With public parks, schools, rehabilitation facilities, and fitness centers closed, concerns of the consequences of the isolation and mental health has started to come to light. COVID19 is making the world move even less than before, and with sedentarism unhealthy behavior also begins to appear.

Many efforts to help people become more active have emerged in the lasts few months. The American College of Sports Medicine has issued guidelines on physical activity during social distancing to incentivize people to stay active, and there has also been a wave of online fitness classes, live workout streaming, and home base solutions. Still, the concern is that the people that did not engage in exercise before the Pandemic are not likely to increase their physical activity during lockdowns. They are more likely to be moving even less.

The virus has altered baseline reality for most of the world, changing hygiene habits to decrease the risk of infection in record time. Maybe it is a chance to modify unhealthy habits like physical inactivity to improve humankind's well

being.

1.3. Challenges in motivating exercise

So how do we motivate people to move? This question that has concerned coaches, professors, mentors, and parents alike still doesn't have a clear answer. There have been studies exploring the drivers of behavior like reward systems, grades, or other's opinions, which are considered external factors or passion and curiosity as intrinsic motivators. Social Cognitive Theory (Bandura, A. 1989) [9] and, more specifically, Self-determination Theory or SDT (Deci and Ryan. 2012) [10] examines the interaction between the extrinsic and intrinsic influences that move human behavior.

SDT identifies two types of motivations that drive human behavior, intrinsic and extrinsic. When a person is motivated intrinsically, he or she experiences joy, personal accomplishment through the application of their skills, and excitement. This intrinsic can sometimes be seen when performed recreational sports [11].

On the other hand, extrinsic motivation refers to behavior driven by an outcome that is separate from the activity itself, for example, when doing an action to receive a reward or avoid criticism.

For this study, I will use the Behavioral Regulation in Exercise Questionnaire or BREQ-2, which was developed to estimate external, introjected, identified, amotivation, and intrinsic motivation for exercise behavior [12]. This way, I can understand the underlying factors for exercise adoption and use them to develop a possible solution.

1.4. Games as an emotional media

When talking about video games, it is essential to define what a game is, needless to say, any video game is a game itself that uses audiovisual technologies. But to answer what a game is, we have to consider terms like play, interactivity, and narrative to understand games better. Eric Zimmermann says that a game is: "A voluntary interactive activity, in which one or more players follow rules that constrain their behavior, enacting an artificial conflict that ends in a quantifiable

outcome." [13]

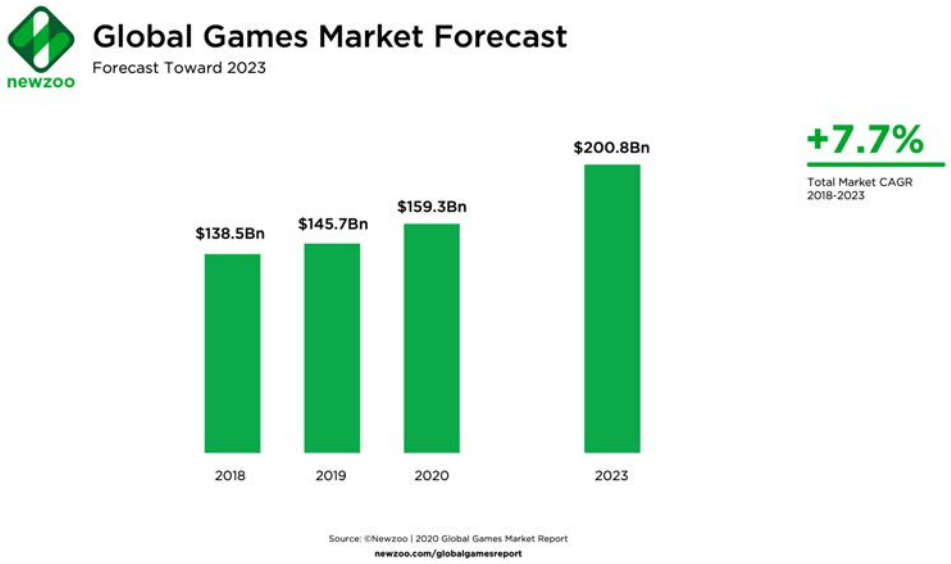
This definition, while accurate, lacks a crucial factor when playing a game, and that is the emotional engagement that comes from the freedom of playing within a set of rigid rules, the pleasure of play. Jasper Juul has one definition that better articulates the essence of what this media is, he says that a game is:

"A based rule system with a variable and quantifiable outcome, where different outcomes are assigned different values, the player exert effort in order to influence the outcome, the player feels emotionally attached to the outcome, and the consequences of the activity are optional and negotiable." [14]

This definition encapsulates the two factors I think are crucial for this study: the player's effort and emotional attachment to the outcome. Let's examine the first. A game needs to be challenging to avoid being dull, and this design feature aims to make the decisions of the player matter so that these choices have consequences and influence the outcome of the game, this is also known as agency.

The second one is much more complex. The player's attachment to the outcome means that he or she might feel happy if it wins or unhappy if he or she loses a particular game. This speaks of what Bernard Suits calls the Lusory attitude [15], which is the implicit contract a player agrees when it enters a rule-based game to seek enjoyment in winning and unhappiness in losing. In other words, it is the mindset of really wanting to win.

But why does this matter? Well, it matters because games have reached a prominent place in world culture. The gaming industry and its revenues are now at the same level as the film and book industry, and they are part of billions of lives worldwide. According to a report by Newzoo [16], the global gaming market will generate $159.3 billion in revenue in 2020, representing a 8.3% growth over a year and projected to surpass the $200 billion mark by 2023. Figure1.3



(https://newzoo.com/insights/trend-reports/newzoo-global-games-market-report-2020-light-version/)

Figure 1.3 Projected growth of the gaming industry 2019-2023

But most importantly, they matter because they evoke meaningful emotions and feelings that drive human behavior. As Katherine Isbister says: "Video game designers are using choices with consequences to move us in fundamentally new ways" [17]. She points out that video game designers are using psychological insights to create more engaging and immersive game experiences.

One example is the invention of the avatar. This innovative medium allows the player to project his personality into the game character creating a kinesthetic connection and inhabiting the problem-solving mind of the virtual persona, making choices within the game that tab into the cognitive flow of a professional skater or a counter-terrorist military soldier. The creation of the avatar changed the video game world fundamentally, crafting a media where people can project themselves into situations that they would not otherwise encounter, turning this feature into a great way of provoking feelings of empathy.

Video game designers have leveraged this insight and have evolved it with customization options that deepen the engagement and creates compelling fantasy worlds where players can act out. (figure 1.4)

(https://www.youtube.com/watch?v=ZXgxLEwt61Q)

Figure 1.4 Avatar customization in is now very detailed

Just as a movie or a novel, games can move us in a way that is worthy of close examination and study so that we can shape the conversation around it. Many still believe that gaming is a bad influence, especially for the younger generations.

Nevertheless, humans are wired to learn how to coordinate with one another and take pleasure in that. In multiplayer video games, for example, people craft actions that create exciting emotions between people. Games and their capacity to evoke

emotions and feelings through game design is a valuable tool to maybe solving humanity's most significant problems by changing human behavior.

1.5. Exergames

The term exergame is a portmanteau combining the words Exercise and Game, and it refers to all video games that use the body as the controller. Premack's principle states that "more probable responses will reinforce less probable responses" [18]. In this case, the less probable activity would be to exercise, and the more probable one would be playing a game. Under this premise, one can argue that exergaming is a "Premackeable" approach to physical inactivity.

In recent decades there has been an increasing number of exergaming studies and games where the body is used as an input that controls a video game's output.

The first record of a corporation embarking is this endeavor is the renowned video game company Atari, which in 1982 created a secret project named "Puffer" [19], a prototype that used an exercise bike connected to their console (Figure1.5).

(https://kotaku.com/atari-puffer-the-wii-fit-of-1982-453119585)

Figure 1.5 Atari's secret exergame project called the Puffer

Despite this product not reaching the market due to Atari filing for bankruptcy before its launch, it did open a new field of video games that inspire others to follow, like the Auto Desk's High Cycle or Racer-Mate which in 1986 created a system with a stationary bike connected to a PC enabling the user to cruise through virtual settings (Figure1.6).

(https://www.newsgroove.co.uk/the-history-of-fitness-video-games-geek/)

Figure 1.6 Computrainer game simulation interface

Another excellent example of the history of exergaming was the Joyboard (Figure3) developed by Atari [20]. This balance board equipped with four trigger buttons beneath its plastic cover was created to emulate a skier's movement down a slope. Little did they know that 30 years later, Nintendo would do a spin off of this concept, calling it the Wii fit.

However, the company Konami created one of the most admired and played exergames in history, the beloved Dance Dance Revolution or DDR. This Japanese rhythm and music video game was released in 1998, and it became an immediate success, turning its players into performance dancers, creating an immersive experience that it was fun to play and fun to watch [21]. The dynamic of the game is rather simple. Players stand on a mat with arrows that serve as buttons, and the purpose of the game is to step on them when on-screen indicators tell them to do it while following a set rhythm, each indicator represents a dance move (Figure1.7).

(https://primetimeamusements.com/product/dance-dance-revolution-extreme-2/)

Figure 1.7 Konami's exergame icon Dance Dance Revolution machine

DDR is the golden icon for exergames, reaching commercial success and respect from video game designers, academia, and sports science.

Several studies have explored DDR's reach as an exertion activity, finding that it has excellent potential to generate a kinesthetic engagement with the payer's body increasing energy expenditure and inducing moderate to vigorous exercise in the user [22].Sports science has also proven the capacity of exergames of improving balance [23], increasing muscle strength, and helping people to stick to workout routines [24], confirming the value that they can offer to the mental, social, and health well being.

1.6. Proposal

Kinix is a connected and adaptive exergame set up that leverages on the advancement of sensor technology, API integration, IoT, HCI research, and game design.

We propose a concept of bio connected exergames that integrate sensor and fitness hardware data and turns them into game input, aiming to generate an immersive experience that can motivate people to move more.

While developing the system, we identified a few research questions that need to be addressed: How come the fitness industry has not been disrupted by new technology? And, How to design an exergame that balances fitness goals and entertainment?

In summary, this thesis provides the following contributions:

- Evaluating the effect of bio connected exergames in regulating exercise intrinsic motivation
- Applying SDT motivation techniques to create a connected and adaptive exergame set up.

1.7. Thesis Structure

This thesis consists of 5 chapters. Chapter 1 presents the background that describes the need for this thesis. Following is chapter 2, where we explore the Self determination theory in exercise and the exergame research as a field and its most recent advancements. Chapter 3 discusses the design process for the prototype called Space Bouncers and a study to evaluate the player's engagement. Chapter 4 showcases the design process of designing Spirit Overflow, the second exergame designed based on the insights gathered by the prototype. Finally, Chapter 5 provides a summary of this work and offers some conclusions and future discussions.

Chapter 2
Literature Review

2.1. Self-determination Theory in exercise

Throughout history, humans have been characterized as a very active organism, but this idea is becoming less accurate when describing modern society, humans. Our Ancestors lived a hectic life, they were encouraged to move and gather resources to keep them alive whereas in contemporary times is quite the opposite, our highly efficient societies rely on our cognitive capacities, leading to more motionless jobs that require us to stay still and look into a screen for hours.

This trend towards a more sedentary lifestyle has taken a toll on our bodies. According to a study from 1975 to 2016, body-mass index or BMI, the standardized measurement for weight status, and the prevalence of obesity have increased worldwide in children, adolescents, and adults(figure2.1) [25].

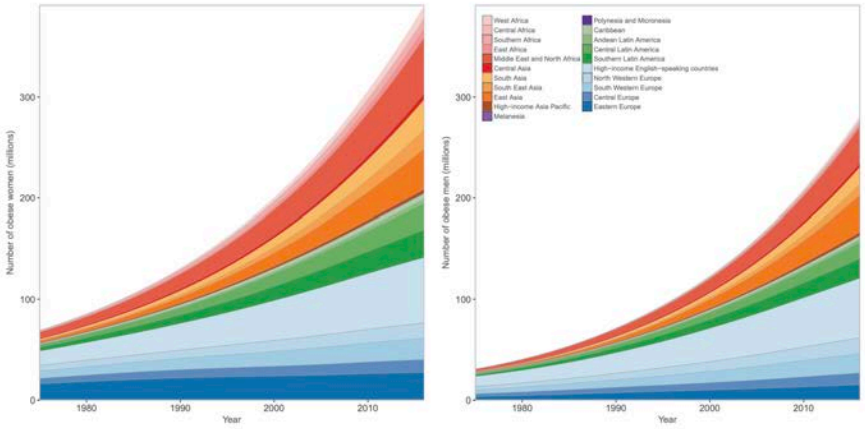


Figure 2.1 Trends in the number of obese and underweight adults (aged 20 years and older) by region

Acknowledging these trends and understanding the importance of motivating physical activity is critical for the future and well-being of the human race. Self Determination Theory is a macro-theory of how humans generate the energy to take action. It can give us some insights into how physical activity is motivated.

SDT begins by making an essential distinction between intrinsic or autonomous motivation and Extrinsic or controlled motivation; these two factors regulate behavior in a continuum manner. The first refers to an experience where the subject has a full sense of willingness, volition, and choice (Deci & Ryan 2000) [26]. In other words, it is an activity that is done with full interest, enjoyment, and engagement. On the contrary, controlled motivation relates to doing something to get a reward or avoid punishment. Either way, the subject will feel the pressure and anxiety, having negative consequences in performance and well-being.

SDT examines Extrinsic motivation as a multidimensional concept consisting of three subcategories (Deci & Ryan, 1985) [27]: External, Introjected, Identified regulation, and Amotivation. External regulation, which refers to the behaviors that are triggered by an external motive like a reward. Introjected regulation refers to the motivation that has been partially internalized but not entirely, like a sense of shame or when we feel that we have to prove something to ourselves.

Identified regulation is when the motivation comes from the appreciation of the value of the activity at hand, and it resonates with one's set of beliefs. A gym-goer when it decides to do an extra set of push-ups because he or she believes that it will help them achieve their fitness goals. SDT also counts for the lack of motivation or Amotivation. This behavior happens when an individual does not feel an intention or sense of impulse to do a set action.

SDT also proposes the concept of psychological needs as part of an evaluation of a whole theory of motivation [28]. According to the theory, there are three needs of the mind that humans need to be experiencing that allow us to develop a healthy life:

Competence: this is the feeling of the effectiveness and confidence of one's skills and capabilities. In exercise, this means the perception of achievement or failure when performing a specific physical challenge, or the resulting feeling of a trainer's feedback [29].

Relatedness: SDT proposes that the feeling of closeness and dependence with

other people is essential to well-being. The concept of relatedness means that sense of connection and belonging to a group when preforming some behavior or action.

Autonomy: Is the feeling of agency and control of one's life. It means the need to feel that the choices taken are the primary driver of one's destiny.

SDT states that, universally, when individuals have these three needs satisfied, they tend to be more autonomously motivated, which leads to a healthy life at a physiology and psychological level. However, these needs and their satisfaction comes not only by the determination of one independent individual but also from a set of social interactions that can create an environment that fosters them or neglects them, affecting the processes and outcomes of the intrinsic motivation itself.

Take sports, for example. When amateurs engage in them, whether it is a young or an adult, their primary reason is to find joy in performing them [30]. However, when parents or coaches become too critical of their performance, they can threaten the need for competence by making them feel inadequate, thus creating an environment where motivation cannot be maintained or amotivation. Players will dropout arguing that this is no longer fun, which can be explained by the lack of the two basic psychological needs of competence and autonomy.

In contrast, studies have shown [31] that when an individual experiences autonomy, competence, and relatedness when beginning an activity, he will be more intrinsically motivated, thus creating a setting where a goal related behavioral change, like exercise, can be maintained.

In this thesis, we will be using the Self-determination Theory as a conceptual framework for autonomous motivation regulation when designing our solution. Taking as key considerations when the following:

1)Exercise can be intrinsically motivated, and by doing it so, we can predict maintenance in exercise.

2)Create an environment where positive feedback encourages the feeling of competence.

3)Design a solution for physical inactivity that fosters autonomous motivation and nurtures the psychological needs for behavioral change.

2.2. Motivation and gaming

As mention earlier, the rapid technological evolution has given game designers more sophisticated tools to create more immersive virtual worlds that enables a new range of activities and behaviors. Gaming is the fastest growing form of entertainment, attracting a wide range of demographic targets, and capturing a large share of their leisure time and economic resources.

The massive appeal to gaming suggests that it is an emotional experience, and that is intrinsically motivated. However, why do gamers spend so much time and money on this form of interactive media? Moreover, when taking into account that it is a media that requires a motivated action from the user when the player ceases to trigger actions, the game ends [32]. SDT can provide a framework to analyze this activity and explain the behavior of the gamer towards it.

One study found that enjoyment is essential when explaining persistence in gaming; they argue that each player chooses a game to satisfy a specific psychological need [33] and achieve that rush of joy. Moreover, they found that casual and heavy gamers were more motivated to play as a result of experiencing enjoyment and a sense of connectedness, Whereas hardcore gamers are more intrinsically motivated when both enjoyment and feelings of competence came into play.

In this thesis, we will leverage the psychological insights of a need-satisfying approach to exergame design to predict intrinsic motivation in exercise.

2.3. The gaming-fitness conundrum

When playful fitness solutions like the Wii Fit and the Xbox Kinect hit the market in the early 2000s, the concept of exergaming found its foothold with a broader audience, evolving from its humble beginnings within a modest community during the eighties. With its emergence, the public perception of exercise and gaming no longer held both categories at arm's length, and the two had started to mingle at a connecting point, set on becoming a class of its own.

2.3.1 Balance

Developing a new breed of technology often comes with its unique challenges that play a crucial role in defining its chances of success. With exergaming, the issue laid primarily in the balance between game features and sport science traits. Fitness game setups in circulation are game-first or fitness-first in terms of their mechanics, and with these asymmetrical priorities came huge drawbacks on the user experience.

Game-first setups may have had found success with the thrill and promise of an interactive experience, but they paid no consideration to the performance aspects necessary for a productive workout. There were no features that allowed users to measure their skill, progress, or even accuracy, making it impossible to determine how effective it is as a tool for fitness.

Fitness-first setups, on the other hand, had the opposite problem. While they presented the user with adaptive workouts that offered accurate tracking devices for measuring progress, it lagged when it came to game design. Barely any thought was put into engaging the user or elevating their experience through exciting game elements.

This thesis aims to provide an exergame solution that helps people find the autonomous motivation to move by leveraging on psychology and game design insights to create a balanced product between fitness and gaming. In this section, we will look into existing exergame solutions.

2.3.2 Game-first Solutions

One of the most commercially successful exergames in the market is Beat Saber, with over two million copies of its game sold [34] it provides a similar level of exercise of a moderate to a vigorous workout routine.

Beat saber is a VR rhythm game. It takes place in an abstract neon based setting where the player has to slice blocks that come his way at the rhythm of the music beat using two saber swords (figure2.2). Beat saber is a perfect example of how, through the Dance Dance Revolution's teachings, we can leverage the power of music and combine it with game design to make people interested and intrinsically motivated to move.

(https://www.youtube.com/watch?v=gV1sw4lfwFw)

Figure 2.2 Beat Saber Game

Nevertheless, there are two drawbacks to this system. The first one is that due to its nature as a virtual reality set up, there have been studies exploring the motion sickness generated by the game, showing that there is a segment of the population susceptible to high symptoms for short exposures increasing the risk of injury [35].

The second shortcoming of this game is that it is a real game first approach to exergaming with little to nothing sports science research behind the game design. This disadvantage has also been seen in the game sector's designs, like the Nintendo Wii, where they feature a sophisticated game design but lack of training concepts that are essential for an effective workout.

2.3.3 Fitness-first Solutions

In contrast, there is a whole sector of the gym industry, combining emerging technology with existing gym equipment; this is the case of Skillrow, Peloton, and Zwift [36] [37] [38].

Skillrow is a rowing gym machine that has incorporated sensor technology that

tracks user performance and displays it in a screen in front of the user and connects to the user's phone(Figure2.3). Even though it is an improvement in the connected gym equipment industry, when it comes to gamifying the experience, they come short by offering reality-based simulators that lack fantasy game scenario design or game dynamics.

(https://www.gymmarine.com/product/technogym-skillrow/)

Figure 2.3 Skillrow technogym set up

In a study done on the user experience of Skillrow, researchers found it difficult to visualize the available exercises and to understand them. Moreover, users reported difficulty understanding acronyms and graphs relative to physical activity results [39],this might be explained by the fact that it is not designed with a gamified human-centered framework that can turn cold numbers into understandable data.

This situation also applies to platforms like Peloton and Zwift, opening an opportunity to innovate.

2.3.4 A flow of balance: A holistic view

To understand what is at stake when developing a new exergame, it is essential to mention that the balance between the game-first and fitness-first approach is a

holistic one that carefully identifies Body, controller, music, scenario, story, and exercise as tools to guide consciousness towards a state of flow.

Flow Research (Nakamura and Csikszentmihalyi) states that flow is a state of full immersion when performing an activity that is rewarding in and of itself and is characterized by the following [40]:

- Intense concentration in the activity
- Merging of action and awareness
- A sense of total control over one's actions
- A lost of sense of time

According to research, this state is an equilibrium between the challenges presented and the perceived action capacities of meeting them. This balance means in game design that the challenges within the dynamics have to be in a sweet spot between challenging enough not to be boring but easy enough not to generate anxiety (figure2.4). If this balance is broken, so is the motivation.

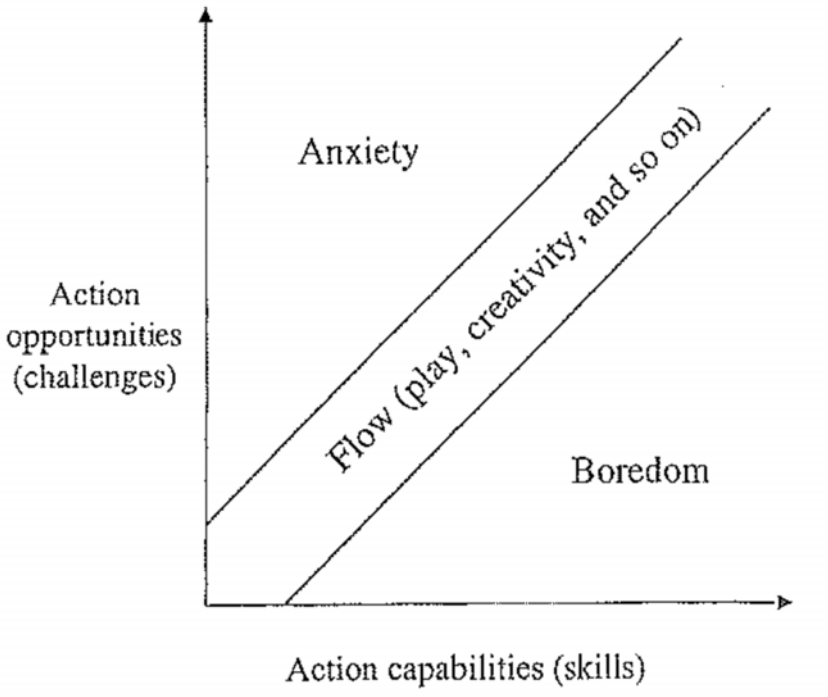
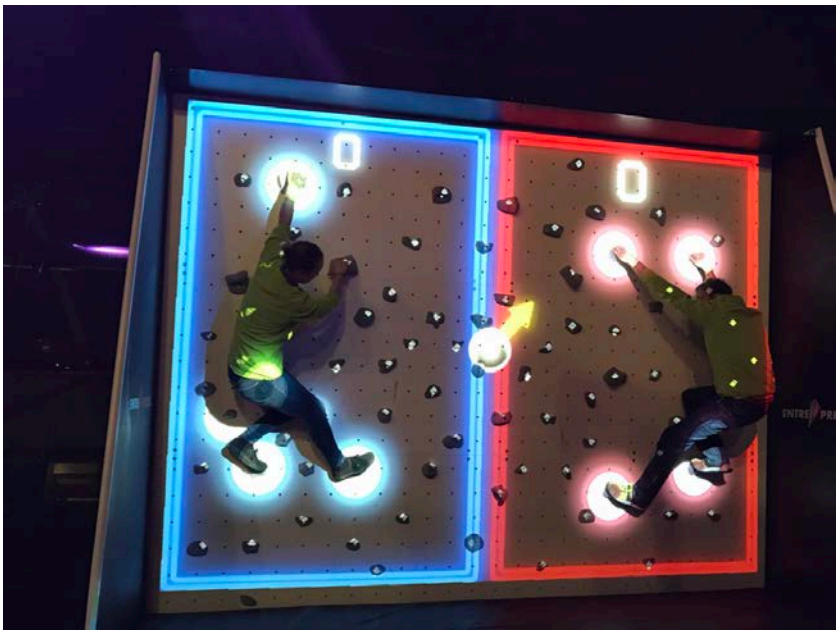


Figure 2.4 "The original flow model state. Flow is experience when perceived opportunities for action are in balance with the player's perceived skills" [Csikszentmihalyi 1975]

With a proper game design, challenges can easily be adaptable to each player generating customization of features. Exergames provide personal challenges, adjustable goal setting, and immediate feedback structures that make flow more likely to happen and maintain.

One of the exergames that have achieved this holistic balance between gaming and fitness is the ValoClimb [41](figure2.5). This exergame created by Axtion technologies is an interactive climbing wall that uses computer vision, video mapping, and game dynamics to enhanced and instruct the experience of indoor climbing [42].



(https://clipnclimb.com/en/blog/augmented-climbing-wall-now-in-clip-n-climbs-portfolio/)

Figure 2.5 ValoClimb game

This set up takes advantage of game design to capture the user's attention and immerse them into a state of flow where they are not thinking about climbing; they are thinking about playing. The system has been tested in different scenarios, targeted audiences, and ages, showing promising results in fighting physical inactivity.

Understanding the Self-determination Theory, we can design games that meet the three primary psychological needs of Autonomy, Relatedness, and Competence to create environments that foster intrinsic motivation. By utilizing scenario design and storylines, we can build immersive narratives that catch the player's attention, and with sports science and machine learning, new algorithms can be produced to reach levels just-manageable for the players and in this way generating the conditions where flow states can emerge. This approach is what we called a holistic view of exergame design.

Chapter 3
Concept Design

3.1. Design Thinking

The role of the designer has changed throughout the last decade. Designers used to work on how to make an already developed idea more attractive to customers. Nowadays, designers are asked to create and design products and services that better fit consumer needs [43]. This shift is a profound change of perspective, moving the designer's attention from what the user says to what the user does.

In this study, we embarked on the design thinking process to explore the new possibilities that the fitness industry offers with the introduction of new technologies like machine learning, biofeedback, wearable, and the internet of things.

The idea of evaluating and analyzing the gym experience is based on my regular attendance at several health clubs for three years. During the last two years, we were mindfully interested in the dynamics of the human-machine interactions and also in the trainer-trainee relations. We elected then to study the gym experience and thus adopted a more rigorous and systematic approach to observation and analysis through the design thinking process.

Design thinking is a non-linear iterative design methodology aimed at understanding users' needs, defying assumptions, defining essential problems, and creating innovative solutions that can be prototyped and tested. This way of thinking strives to help designers learn new things with each iteration of a prototype rather than just trying to prove a hypothesis.

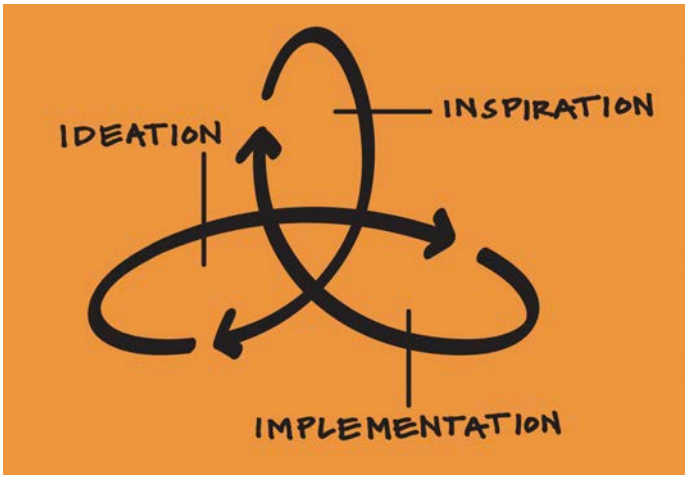


Figure 3.1 Design Thinking process by Tim Brown IDEO designthinking.ideo.com

For this study, We went through the design method's three main spaces: inspiration, ideation, and implementation.

3.1.1 Inspiration

For the inspiration space, We wanted to learn how gyms worked from the inside, gaining an empathetic understanding of the underlying relations between gym goers and their trainers, engaging with these people's experiences and motivations, and immersing our self in the physical environment so we could know the issues involved.

We conducted three field research in 3 gyms where we observed the users and also conducted interviews with different collaborators to know their needs and wants to understand the problem or find an opportunity to motivate the prior solution.

The first one was the KONAMI sport's Club. This franchise, part of Konami Holding, which has businesses in the entertainment, gaming, and fitness sectors, is considered the biggest in the world, with over 262.5 billion JPY revenue in 2019 [44] and is the creator of one of the most beloved games, and an inspiration for this study, called dance dance revolution.

We visited the Musashi-Kosugi location, where we were greeted by one of the trainers who agreed to an interview and a tour. He did not consent to be recorded

nor to use his name; nevertheless, he was open to responding to any questions during our time in the facilities. Figure 3.2

Figure 3.2 Konami Sports Club Mushashi Kosugui www.konami.com/sportsclub

The second field research was conducted in Central Sports gym located in Hiyoshi. There, we met with the General manager who received us and our translator and took us through a tour of the place while we interviewed him. He showed us how the gym manages the user's history and workout sessions which to our surprise was all done in paper and pen and archived in large rooms. Here we got a chance to talk to an elderly gym goer and interviewed him on his experience, workouts and opinions. figure 3.3

Figure 3.3 Central Sports Hiyoshi location www.central.co.jp/club/cw-hiyoshi/facilities

Keio University's Hiyoshi campus gym was our third field research. This charm-

ing gym is a student-managed space where faculty and students gather to exercise using free weights and machine-based area. Here we was able to interview several gym users and a trainer. figure 3.4

Figure 3.4 Keio University's Student's gym

3.1.2 Field research insights

Afterward, we analyzed the 3 locations with their respective interview and started looking for coincidence from the stakeholders, the facilities, and the needs of gym-goers and trainers alike. Three main insights were revealed, which we summarized here:

- Lack of a technological system that tracks and optimizes the workout plan of each customer:

  This was a common aspect in all three gyms. Some of them like The Konami Sports center and Central Sports have newer equipment like treadmills with televisions where the user can watch a wide range of live channels, have their Heartbeat measure and have information about their session tracked.

  Nevertheless, none of the cardio gym equipment had any storage system or connection to the internet, and there is no technological method to track the exercises from the weight section leaving the data generated by the user at every session lost. Another striking discovery was that all of the gyms used a paper-based system to follow up with each member's workout plans, in one of the interviews, we even witnessed one of the trainers misplace one of a members workout plans.

- People are motivated to engage in fitness if it is fun:

  This insight was found in elderly gym goers and young students. The elderly gym users manifest that they enjoy arranged classes by the fitness clubs where they share a space with other people, and an instructor guides them through aerobic exercises. This finding correlates with some studies that suggest that group-based activities show better results than those that exercise alone when weight loss is a measure [45]. In the younger audience, we observed from the interviews that students that went to the university's gym tend to invite another friends to train together. They stated that they found the experience more fun when shared with one or two friends.

- Users want to track their performance.

  When starting any physical activity, one concern is where to get the proper information on what exercise to do, how to do it, and for how long. During the interviews, we found that the elderly are more dependant on the human trainers to get this information, whereas, for the younger audience, digital platforms like Instagram and trainer apps are the go-to places for workout routines. What they had in common is that both manifested a desire to have a system in place to follow their performance and workouts.

  Nonetheless, the gym's official way of tracking their workouts is by using an analog pen and paper system that the trainers update each time the users finish a routine. Some of the students interviewed used their trainer's apps and wearable technology to log in their workout routines, saying that they could get more feedback this way. Many studies have found the link between tracking performance with technology and the optimization of workouts [46] [47].

  When it comes to understanding the variations the body goes through when it engages with exercise for over six months, tracking systems can be a powerful tool to make the small changes evident and optimized the exercise experience for everyone.

3.1.3 Problem definition

Once we conducted the interviews and survey and analyzed the results and insights, we realized that for a share of the population motivation regulation for exercise comes mostly from controlled motivation or internalization of extrinsic motivators, thus making it difficult to maintain it in the long term producing most people to quit their work out plans. How can we create environments that foster an intrinsic motivation towards exercise so that people motivate themselves to move more?

3.1.4 Ideation

Once we defined the problem we want to solve, we started a series of 2-hour design sprint sessions where we came up with more than 50 ideas that could potentially be effective in solving the problem in hand, Almost all of the ideas circle around a variation of three components: entertainment, biofeedback, and social incentive.

We found inspiration in one place where people go voluntarily and spend hours weekly doing an activity that requires high focus and sometimes physical activity: A video game arcade shop. Arcades are commercial establishments that offer a variety of coin-operated electronic video games. These places had their golden age at the end of the 1980s, where games like Space Invaders and PAC MAN became world pop culture icons.

Nowadays, Arcades continue to be popular in places like Japan, where they take several buildings full of the most diverse options of video games and controllers that players could not get at home. As we mentioned earlier, new technologies like Kinect, sensors, IoT, and machine learning have opened a whole new creative path for arcade game developers.

Popular franchises like Dance Dance Revolution, where the player uses the body as a game controller, created a new genre of video games called exergames or exertion games, where the idea is to use game dynamics to satisfy the user's psychological needs and intrinsically motivate users to move.

We started choosing a name for the project, we explored various names, but we wanted to portray and communicate that everything we were going to create aimed to solve the physical inactivity pandemic, so it needed it to convey that

we wanted to make people move. We came across the Greek word Kínisi which means physical movement, it resonated with the ethos of the project so we did a spin-off of the word by adding an x to the end to make it sound contemporary and the Kinix was born.

Kinix is a project that aims to design a fully connected exergaming experience where we combine the best of the attractiveness of the game design and the health benefits of exercise to create an entertaining workout space that keeps the user intrinsically motivated. This concept would merge game dynamics, sports science, Self-determination Theory, HCI, and machine learning into a biofeedback exercise experiment that would optimize and personalize workouts and track performance and well being.

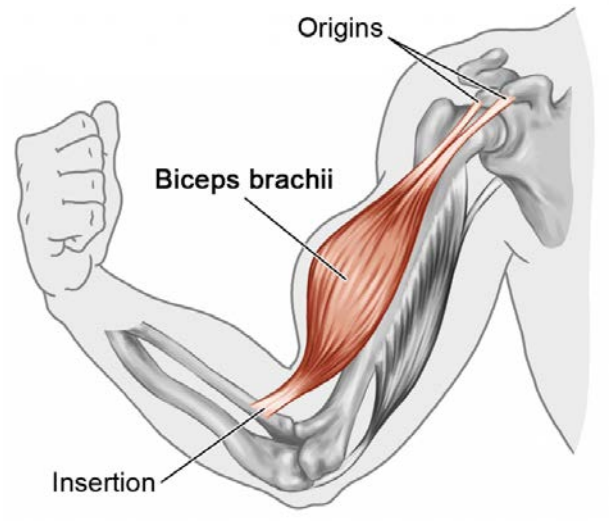
We set out to design our take on an exergame, so we decided to take this approach to exergame design: we wanted to Sportify a game instead of gamifying a sport. Let us examine the second part: by avoiding the gamification of a sport, we willingly decided to avoid the concept of turning a real-life sport into a video game, like for example Wii tennis, under the premise that if someone would like to experience the game of tennis well, it is better to grab a racquet and hit the court.

In contrast, by using the sportification concept, we would open a more creative path to designing our game. Sportification is the "organization of a non-sport activity in such a way that it resembles a sport and allows a fair, pleasurable, and safe environment for individuals to compete and cooperate [48]."With this in mind, we started ideating in games that we could turn into a physical e-sport.

In our research, we found that not many exergames focused on muscle strength, so that was the direction we decided to take. Inspire by the works of Dr. Nadia Hernandez, mentioned earlier, we wanted to create an embodied interaction that creates a kinetic connection between the player and the character.

In this section, we will go through the design of creating a muscle-based HCI game controller that involves more body movement as the means to achieve a more compelling experience.

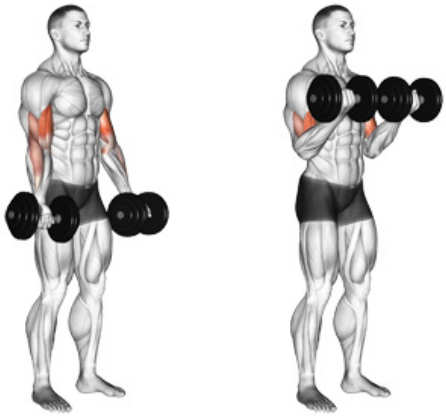
To implement our proof of concept, we proposed designing, developing, and testing an Electromyography biofeedback exergame that uses the long head of the Bicep Brachii muscle to control a video game character. (Figure3.5)



(https://www.oldschoollabs.com/hammer-curls-vs-bicep-curls/

Figure 3.5 Bicep brachialis muscle

We used the bicep curl as the main exercise. The bicep curl is an exercise in which an individual bends his arms to curl (Figure3.6) the weights to their shoulders, and then lower the arms to the starting position, it is a repetitive movement that activates the bicep brachii directly. We chose the bicep curl because it is a repetitive motion not intrinsically enjoyable, so we hypothesized that with our system, we could foster autonomous motivation.



(https://viceversar.com/2020/04/10/how-to-perform-hammer-curl-biceps-exercise/)

Figure 3.6 Free weight exercise Bicep Curl

Once we had decided on an exercise, we started ideating on the different game dynamics that could work with the limited motion of movement given by the bicep curl. We begin exploring the possibilities of manipulating motion with each flex (figure3.7) and, in this way, controlling a continuous shooting spacecraft (appendix images of ideation). Even though the idea of a space fantasy story line was very appealing, the dynamics of a game like this could create problems of executing the exercise in a fast or careless way, and that could lead to a risk of injury.

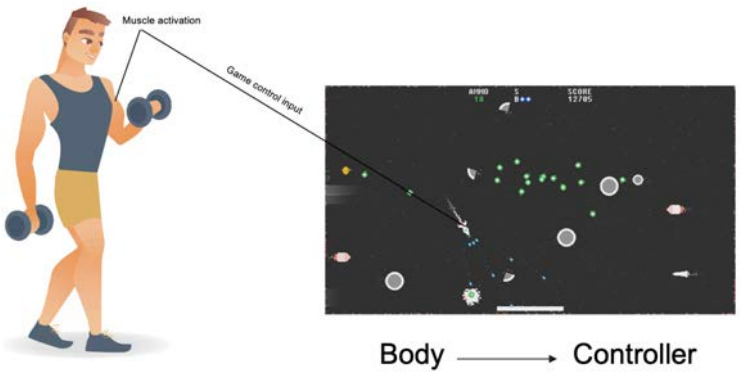


Figure 3.7 First game idea

We then found a game genre called platform jumping game that gave us the

tools to properly design the dynamics to guarantee a safe pace while creating a fantasy story line that could be engaging (figure3.8).

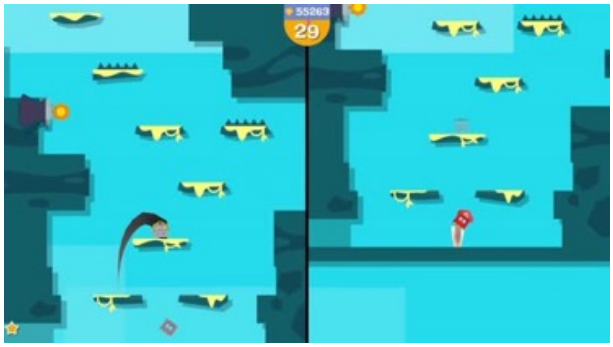


Figure 3.8 Jumping Platform game reference

3.2. Kinix's first Prototype

When creating the layout, we wanted to create a beautifully designed game that had a story line that has fantasy and relatable characters. We chose Space Bouncers as a name for the game. (figure3.9).

Figure 3.9 Space Bouncers game Key visual design

Space Bouncers takes place in a far galaxy where a crew of brave space explores cruise the universe in search of quantum rocks, the primary fuel resource for their civilization. In one of their adventures, the evil Warudemon, the crew's most

feared antagonist, ambushed them and took them all hostages except for their captain QuiQui.(figure3.10):

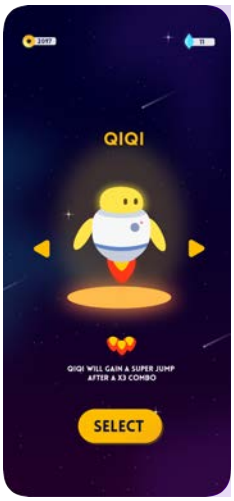


Figure 3.10 Space Bouncer Character Design: QuiQui

QuiQui's objective, and the main player's, is to bounce through the universe, find his crew, and save them from the evil hands of Warudemon.

The game play dynamics consist of users intuitively controlling the jumping direction of the game's main character by flexing their arms using a pair of dumb bells. Once the player has completed, he or she has performed a complete bicep workout session without noticing it. The primary game dynamics went as follows(figure3.11):

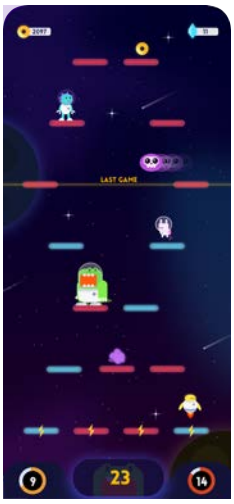


Figure 3.11 Space Bouncer User Experience design

- Avoiding enemies: there are three types of enemies foul platforms, enemies, and poison. The first two would make the point counter reset to zero, and the third enemy would narrow the player's view, so that has to move more cautiously.
- Collectables: there are coins and gems spread throughout the game for the player to collect to unlock new features and characters.
- Combos: by jumping in three platforms of the same color, a super jump is triggered to get more height hence more points.

The game was designed to guide the execution of several consecutive muscle contraction-relaxation cycles following specific bicep curl exercise parameters.

3.2.1 Hardware and software

The game integrates an explicit EMG biofeedback mechanism that lets the users control the main character based on their Bicep brachialis muscle activity.

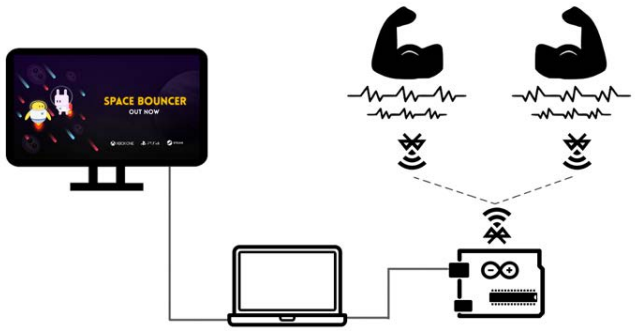


Figure 3.12 Space Bouncer hardware set up

The EMG-based exergame platform incorporates two sEMG sensors, each controlled by an Arduino Nano that sends data wirelessly through an HCO5 Bluetooth module(figure3.12) to an Arduino Mega connected to a laptop. The laptop runs one exergame, built using Unity.

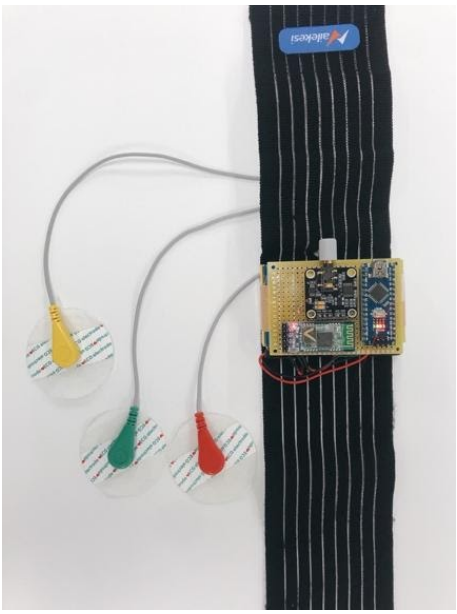


Figure 3.13 Hardware: EMG Sensor, Bluetooth module, Arduino

Each sEMG sensor and its respective Arduino, Bluetooth modules, and batteries are mounted on a Velcro armband (figure3.13) wrapped around the user's biceps

(figure3.14). A Television display in front of the users displays the game.

Figure 3.14 Armband set up

Chapter 4
Study and Evaluation

4.1. Overview

To evaluate Kinix's concept, we conducted a study to assess the level of intrinsic motivation each player experience during the gameplay. We also exhibited kinix in several demo days and managed to gain valuable insights into how kinix can be applied to different scenarios.

4.1.1 Participants

Four healthy volunteers, two males, and two females were recruited from the Keio University KMD Faculty. All participants were between 26 and 35 years old, and they all gave written informed consent (AppendixA).

4.1.2 Procedure

At arrival, participants were briefed about the nature of the experiment, the data measured, and the anonymity of the collected information, a written waiver was signed for video recording.

After explaining the storyline and information regarding the rules and the main elements of the game, the users choose the difficulty by selecting the weight of the dumbbell set.

The user plays the exergame and does the equivalent of 3 sets of 12 repetitions in 2:30 minutes. After they finished, they completed a 25 question Likert survey to assess gameplay features like Accomplishment, challenging competition sense of guidance, immersion, playfulness, and sharing.

Measurements and analysis: We used two main ways of gathering data: a webcam located on the top of the game display to analyze the player's posture(Figure. The level of motivation was assessed using an Intrinsic motivation inventory (IMI) questionnaire combined with standard gameplay assessing questionnaire. (appendixB)

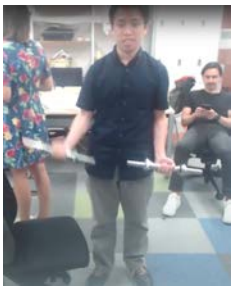


Figure 4.1 Participant A

Figure 4.2 Participant B

Figure 4.3 Participant C

Figure 4.4 Participant D

The survey was provided once the user finished the game. Each question was scored on a 5-point Likert scale (From 1 - Not at all to 5- Extremely).

4.1.3 Results

Results IMI results suggest that performing the bicep curl exercise with the proposed game platform leads to higher intrinsic motivation levels than a standard Bicep curl gym training.

The survey also showed a lack of sense of guidance in the game, which is very important for exergames with a mean calcification of 2.25. It ranked as the lowest-rated feature in the game.

Game features Mean classification:

Game Feature	Mean calification
Accomplishment	4.16
Challenging	4
Competition	4.5
Sense of Guigance	2.25
Immersion	4.12
Playfullness	4.2
Sharing	3.12

Figure 4.5 Mean Qualification of each feature measured on the survey

During each user test, we recorded video, and then it was analyzed to see how the players reacted to the game and how well they were performing the exercise. Results revealed that two out of the four participants were engaging in incorrect posture while performing the task.

4.2. Kinix as a Super Human Sports Project

We had the opportunity to exhibit our Kinix Game in the Super Welfare expo [49] in Shibuya during the study. The event promotes diversity in Tokyo by breaking down social barriers for people with disabilities. In the 2019's edition, the event showcased Kinix as part of the Superhuman Sports Society [50], a project that explores how sports evolve with emerging technologies towards a more inclusive future.

During this exhibition, we managed to show the designed exergame setup to people with disabilities and decision-makers like former Minister of Education, Culture, Sports, Science, and Technology Mrs. Tomoko Ukishima (Figure4.6) and gather their insights on how this approach to exergame design can be developed to meet their needs.

Figure 4.6 Kinix booth at the Super Welfare Expo 2019 Mrs Tomoko Ukishima listening to kinix presentation.

4.2.1 Feedback from the fitness community

We tested the Setup with three Dunlop Gym's staff members and collected their feedback(figure4.7). Trainers said that a set up like this would help them attract new customers to the gym and help people have more compliance to their workout routines. They also mention that can help people be motivated to train since the game gives positive feedback along the way, they argued that for example, for the elderly gymgoers, they sometimes use video tutorials withing the gym to guide the session, but some customers complain because of the lack of interactiveness. The gym manager mentioned that it could also be multiplayer so people can interact with others during the workout session. Nevertheless, we would need more research to develop a more plug and play experience for older adults.

Figure 4.7 Dunlop gym showcase to staff members, trainers and managers

4.2.2 HCI and exergame community

We got invited to participate in the international sports and technology association called the Power of Play, where researchers from all over the world come together

to share their experiences and research on exergames. We got the chance to showcase our set up to Professor Tom Fritz, a brain researcher leading the Max Planck Institute for Human Cognitive and Brain Science in Leipzig [51], and the founder of Jymmin [52] a company aimed to develop scientifically validated creative musical exertion technology that contributes to physical inactivity. Both Dr. Fritz and Dr. Eckehard Fozzy Moritz, a German entrepreneur and physical activity importance advocate, tried our solution and gave valuable feedback.

For them, the idea had potential, but the approach of connecting the muscle activity through a complex system like the EMG was overkill in terms of development and recommended a more plug and play solution that showed the bio connectivity more in terms of game dynamics and not as input for the character.

4.3. Summary

The proposed system performed adequately in a lab and controlled scenario. The small size but representative control trial test the users reported high levels of feelings of Accomplishment (4.16), Challenge (4) and playfulness (4.2) suggesting that the psychological need of Competence was met, thus creating an enjoyable game and an atmosphere where intrinsic motivation towards performing a repetitive movement exercise can increase. These preliminary results are encouraging and may indicate that Space bouncer as an exergame can have significant implications in creating a set up that fosters intrinsic motivation for exercise.

Furthermore, the study also highlighted the need for more guidance within the gameplay to assist the player in the correct movements better.

A possible solution can be to use a Kinect to track the user's body and a machine learning algorithm that can detect the bad postures and the proper ones and we can use that input to trigger new in-game incentives to guide the user in a seamless way to a better position and overall muscle training experience.

In future iterations, EMG sensors can be used to estimate muscle fatigue during isometric and isotonic exercises. It is possible to design a machine learning model that learns the EMG signals that alert the user when the muscle is close to fatigue or failure, avoiding injury.

This same data could be used to adapt the training sessions to each user so

that the workout plan can be personalized to each user depending on his or her progress.

Finally, data could be upload to the cloud and shown in a digital app to show the user their progress in a gameplay manner so they can share with friends or download the raw data to share with a medical consultant.

Chapter 5
Holistic Exergame design process

5.1. Concept Design

After designing the prototype, we consider that there are various aspects that we need to consider in creating a holistic exergame design, and they involve psychological, game design, and sport science features. We then set out to design a new immersive and bio connected fitness setup aimed for in-home use with what we had learned.

In this chapter, we will explore the iteration process that we went through to create our proof of concept. The development followed an integrated design approach consisting of dependence between fitness concepts and game mechanics, with a need-satisfying psychological procedure to generate an environment to foster autonomous motivation to exercise.

5.1.1 Design considerations

We derive some design considerations that address both the functional and effectiveness of a holistic exergame according to our study and feedback from the various exhibitions. First, we realized that the EMG hardware technology that we were working with was not reliable enough to have consistent data, and the consistent ones, did not fit our set budget. Because they need new electrodes for each user and the time to set up each player was an average of 4 minutes, we considered them not viable for our iteration. We decided that we need it to have a more plug and play approach that had little to no preparation time to start playing.

Another consideration was that we wanted to design having the SDT as a base to tackle not only the fun-fitness problem but also the psychological needs humans

have (Autonomy, Connectedness, and Competence). We develop the following model guide for designing Exergames (Figure5.1).

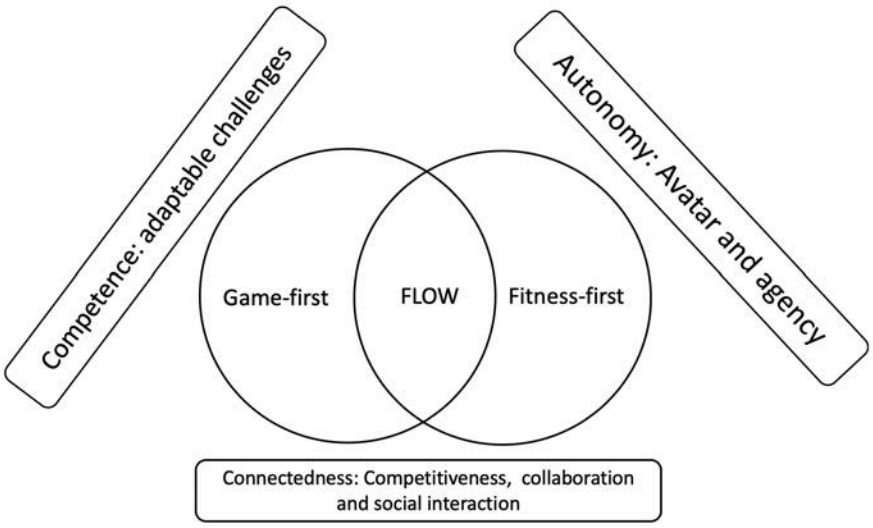


Figure 5.1 Exergame Design framework

5.1.2 Inspiration

We got inspired by the origin of exergames, Atari's secret project that connected a static bike to their 2600 console device called the puffer. Our primary influence was that by integrating existing fitness and gaming technologies, we could focus on software development instead of building hardware from scratch.

However, we also wanted to take it one step forward and design a new exergame. Still, we also envision a digital platform where the data generated by the exercise could be store and analyzed, hence changing the way workouts are tracked using paper and pen.

Having this in mind, we started ideating on different solutions that fitted or new conceptual framework.

5.1.3 Ideation

We conducted an ideation workshop where we sketch more than 20 ideas and drafted 9 of them (C). We examined different gaming genres, gym equipment, smartwatches, and fitness applications to understand how they could be more integrated. We saw a vast amount of fitness apps, wearables, and connected health equipment being developed, but not so many software integrates them and makes sense of the correlated data. We saw here an opportunity.

We started ideating on a digital platform that could integrate all fitness connected equipment and use them as consoles for newly developed exergames. A centered Game distributor that contained all games and hardware integration's. (figure5.2).

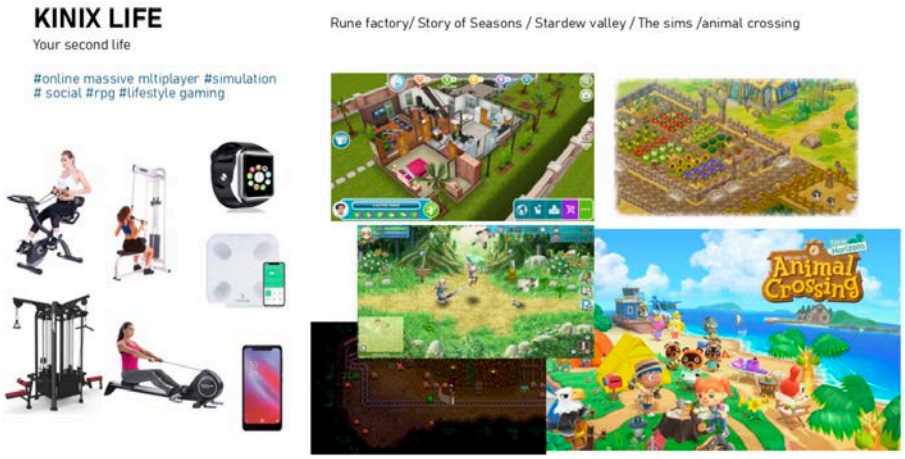


Figure 5.2 Centralized Game distribution idea: Kinix life

To make this idea a proof of concept, we proposed a new bike based turf wars exergame having as inspiration games like splatoon and paperi.io, which are multiplayer territory game where the goal is to conquer as much territory as possible while trying to outwit the competition. (Figure5.3)

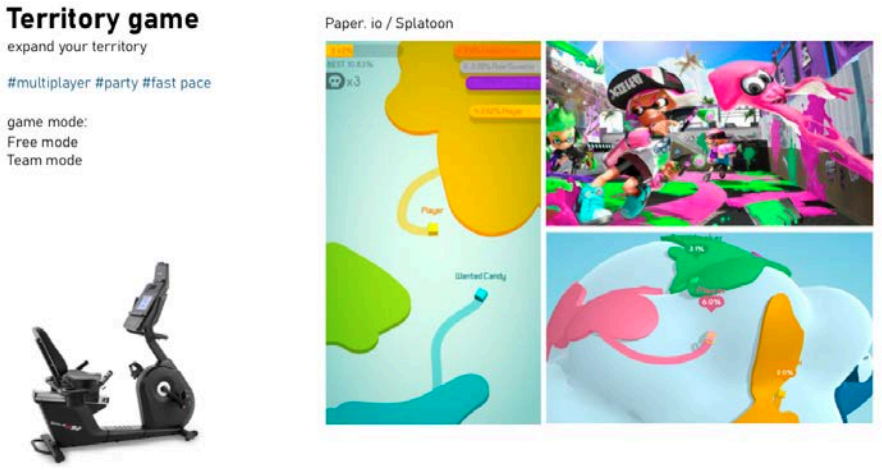


Figure 5.3 The idea is to sportify the territory game using fitness hardware

Once we had the idea, we surveyed to see if people were interested in a home bike exergame. A sample of n=27 individuals (Mean age= 33.2 SD=12.53), where 63% are female (17), 33.3% are male (9) and 3.7% prefer not to say (1) who stated that they lived in Colombia 25.9% (7), Japan 22.2% (6), Netherlands 3.7% (1), Norway 7.4% (2), UAE 3.7% (1), U.K 3.7% (1), USA 25.9% (7), Vietnam 3.7% (1) and Canada 3.7% (1) .We asked the question: Would you willing to try a bicycle-based multiplayer online competitive exercise video game? (figure5.4)

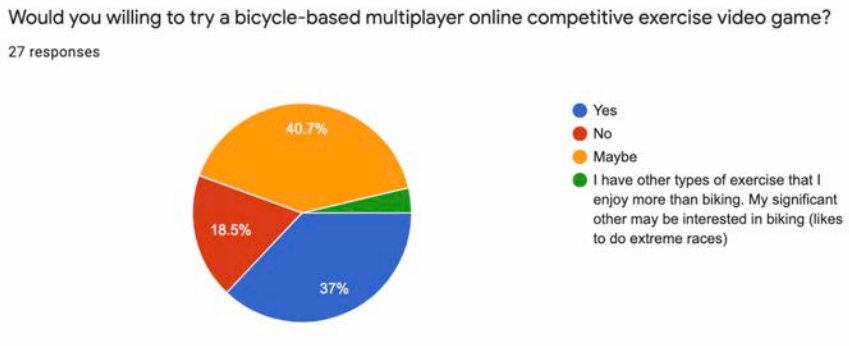


Figure 5.4 survey to ask if people were open to a solution like Spirit Overflow

Results showed that 37% of people are interested in trying a solution like the one we were proposing and 40.7% are open to the idea. With this confirmation,

we embarked on designing and developing our exergame.

5.1.4 Proof of concept

We started by choosing an intuitive human activity, bike riding. Cycling provides a moderate to vigorous exercise. Studies have found associations between 30 minutes of daily cycling and body mass index reduction, blood pressure benefits, and improvements in cognitive functioning and anxiety reduction [53].

It is rational to argue that an engaging bike exergame can contribute to the inactive population's well-being. That is why we create Spirit overflow. (figure5.5)

Figure 5.5 Spirit Overflow original Cover

5.1.5 Prototype

Spirit Overflow is our second game, where we combine cycling with fantasy game dynamics. By integrating existing home exercise hardware like a bike trainer, a smartwatch, and a mobile phone, we create an ecosystem of technologies that work together to deliver an immersive game that makes the user sweat.

The game takes place in a distant future in the year 2100 in Neo-Tokyo, where bike gangs are at war to control the city. When someone is killed in the streets,

the bands take ownership of their digitized soul and keep them as trophies. They have chosen to create an arena on a rooftop in Shin-Shibuya (figure5.6), where they put their prisoners to battle for their souls in a turf fight where they use their bike skills to take the most territory. (Figure5.7)

Figure 5.6 Spirit Overflow original art of the arena

Figure 5.7 Spirit Overflow territory game

As for character design, we choose to create avatars that contrast with personality color and gender , each one created from original sketch art and model into 3d (Figure5.85.9). The look and feel of this immersive exergame were inspired

by the cyberpunk theme that is one of the upcoming trends in gaming and can appeal to a broad audience.

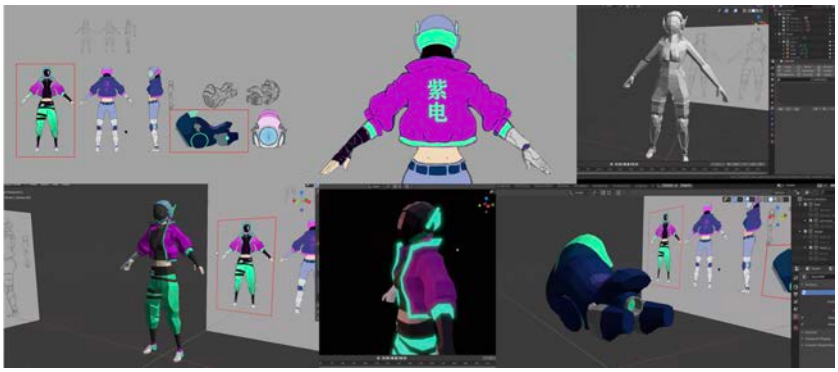


Figure 5.8 Character 1 design process

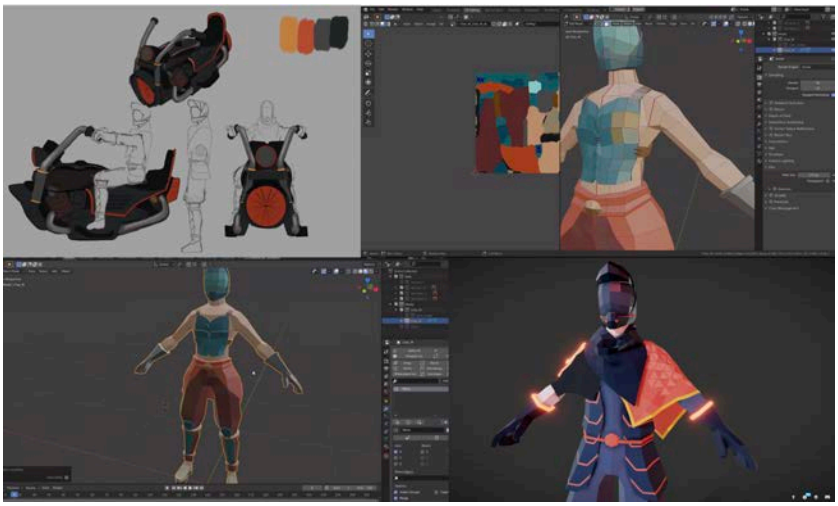


Figure 5.9 Character 2 design process

Spirit Overflow original audio design covers a particular design set of feedback sounds and atmospheric landscape that reflects the futuristic theme and incentives a powerful workout.

Spirit overflow is an exciting competitive multiplayer online exergame designed with esports elements in mind. These include turf wars, team roles, and strategies to engage with a broader audience and create a space where they can motivate themselves to move. (Figure5.10)

Figure 5.10 Character selection screen

5.1.6 Set up

The game allows players to ride their bikes on stationary trainers while battling with other players in a futuristic cyberpunk Tokyo. For this to happened, we developed an android app that serves as a hub and connects to the bike trainer, the smartwatch, and the display. The game was built using Unity, and through OSC messaging, the android app sends the data to Unity, where the engine than makes sense of the data and runs the game (figure5.11).

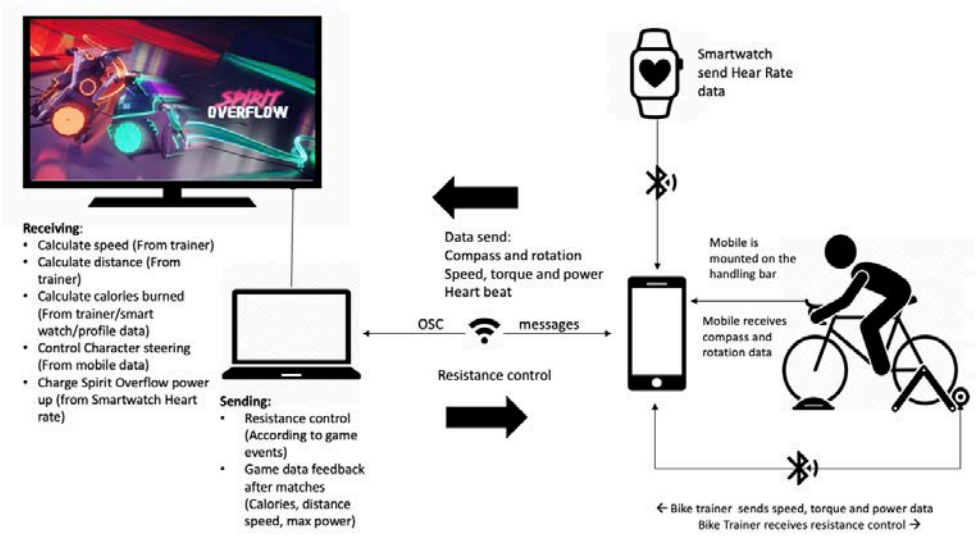


Figure 5.11 Technical set up

We used wahoo bike trainers that use ANT or Bluetooth Low Energy technologies to transmit data like speed, cadence, and power. This Smart trainer includes embedded a power meter that allows us to measure data very accurately and use applied resistance to add haptic responsiveness to the game mechanics(figure5.12).

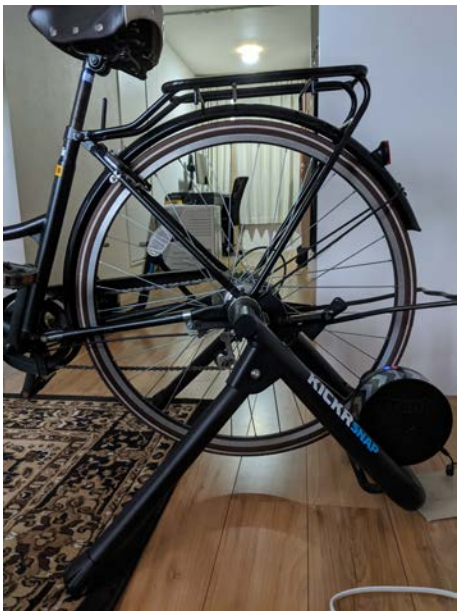


Figure 5.12 Bike trainer)

Another integration is with the polar M200 and M430 smartwatches models. According to their manual, they use a technology called optical heart rate monitoring (OHR), which works by shining an LED light through the skin. A photodiode detects the intensity of the light reflecting and measures this variation, thus determining heart rate and calorie consumption [54]. Figure5.13

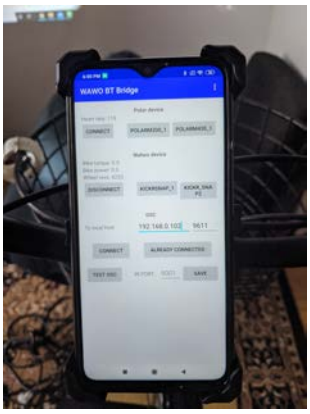


Figure 5.13 Mobile android app receiving data from the smartwatch and the bike trainer

Heart rate is one of the parameters to measure if the game is challenging enough. We used an adaptive system informed by previous related sports science work to calculate age-predictive maxim heart rate (figure5.14). We created a game dynamic where the heart rate target range (from HR target= 120 to 180 depending on bio data) activates a supercharge of power-up. When it reaches full capacity, it triggers releasing a Spirit Overflow 20 seconds of super immunity and speed. This dynamic is to motivate just-manageable levels of adaptive challenges to motivate vigorous exercise and achieve flow. (figure5.15)

Figure 5.14 Heart rate range system that adapts to each users profile bio data (Age, weight, height, gender)

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

Figure 5.15 Real in game image explaining the user experience of how the heart rate affects the game)

The mobile phone has two main characteristics. It works as a data receptor of these two fitness hardware devices via OSC messages to send them to the game, and second, by using the inbuilt gyroscope sensor, it serves as a controller for the steering sending compass and rotation signals to the game. (figure5.13).

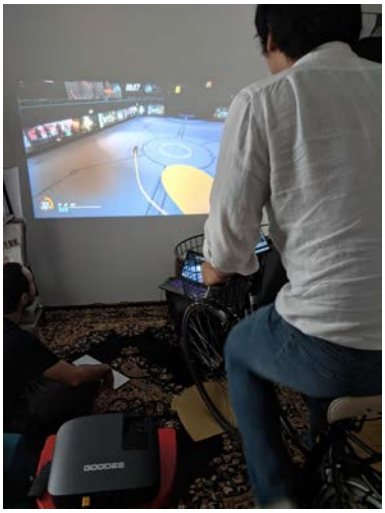


Figure 5.16 Real prototype set up process)

We have had the chance to try the system in a small niche of people from the exergaming community who manifested experienced a demanding workout while

being immersed in the game.

Figure 5.17 Prototype testing)

5.2. Evaluation

Towards a better understanding of our system and how it serves its purpose of creating a space and set up that fosters an intrinsic motivation to move more, we propose to preformed a study. We propose to test the set up and its effect

5.2.1 Overview

Towards a better understanding of our system and how it serves its purpose of creating a space and set up that fosters an intrinsic motivation to move more, we propose to preformed a study. We aim to test the setup and its effect on exercise motivation, endurance, and effort using heart rate monitoring and an Intrinsic Motivation Inventory questionnaire, a standard Self Determination Theory device designed to assess user's subjective experience associated with a specific activity in lab experiments.

5.2.2 Hypothesis

We hypothesize that with our Exergame setup, a user's intrinsic motivation towards riding a bicycle will increase, thus exercising more vigorously.

5.2.3 Participant

One 34 year old healthy female recruited from Keio University's KMD faculty. She signed written informed consent.

5.2.4 Procedure

At arrival, we briefed the participant about the nature of the experiment, the data measured, and the anonymity of the collected information, a written waiver was signed for video recording.

The participant was asked to ride a bike installed on an electronic trainer for 30 minutes without playing any game music or other stimuli (figure5.18). Her heart rate was recorded during the session for future analysis. Once the 30-minute bike session was finished, she responded an Intrinsic Motivation Inventory questionnaire (AppendixD).

Figure 5.18 Participant riding the bike without the game

After resting for 10 minutes, we proceeded to explain the storyline and information regarding the rules and the main elements of the game Spirit Overflow, the user chose a game character and proceeded to play three sets of 10 minutes each. After finishing the three sessions, the user completed an 18 question Likert

survey to assess interest, enjoyment, perceived competence, value, and effort while playing Spirit Overflow.

5.2.5 Measurements and analysis

Both Questionnaires with and without the game included the same 17 questions, distributed in 4 subscales: Interest/Enjoyment, Effort, Perceived Competence, and Perceived Value. Interest/Enjoyment items 1,2 (R),3(R),4 (e.g., I thought this activity was quite enjoyable); Perceived Competence items 5,6,7(R),8, (e.g., I was pretty skilled at this activity.); Effort items 9(R),10,11(R),12,(e.g., I put a lot of effort into this.): Perceived Value items 13,14,15,16,17,(e.g., I think doing this activity could help me to improve my endurance).

We then calculated each subscale score by averaging the item scores each subscale to identify if there was any difference with the game and without the game. We also recorded heartbeat activity during both sessions to compare the differences.

5.2.6 Results

All descriptive values and test results are listed in the table below. figure

To score and analyze the Intrinsic Motivation Inventory subscales we began reverse scoring the items with an (R) by substracting the item response from 8 and then use the resulting number as the item score and then calculated the average scores (figure 5.19)

VARIABLE	NO GAME	GAME
INTEREST/ENJOYMENT	1.75	6.25
COMPETENCE	1.75	4.25
EFFORT	1.5	6.5
VALUE	5.75	8.75

Figure 5.19 Mean score calculation for each variable

Comparing both activities, with the game, the user reported higher interactivity levels, and a feeling of challenge and engagement with the graphics and audiovisual

cues, increasing the users' interest and enjoyment levels (Figure . When compared with the no game setting interview, the participant said that she bored very rapidly and reported cognitive underload, confirming the premise of flow theory of skills being underused by the challenge.

Figure 5.20 Participant playing the game

For Spirit Overflow, the user reported feeling absorbed by the game's audio-visual aspects and dynamics, pushing her limits to achieve and perform better, this effect is evident in the difference in the effort variable subscale of the IMI questionnaire. Moreover, one of the key features that the user highlighted was the resistance feedback that the game did when the user tried to invade enemies territory, it was an element of surprise that made her workout harder in a playful way.

Effort and interest/enjoyment were the two main variables that seemed to stand out. This was also confirmed when we analyzed the heartbeat data during both sessions. During the bike riding sessions with our a game, the Samsung galaxy watch reported an Average Heart rate of 109bpm, a max of 120bpm labeling the sessions as moderate exercise. In contrast, when playing Spirit Overflow, the data showed and Average Heart Rate of 110bpm and a max of 136bpm, reaching more than 2 minutes of vigorous exercise(Figure5.21). When Calorie burning

was examined, the game session burned 5 percent more calories that the session without it, confirming that the user performed better with the system, suggesting that the user was more intrinsically motivated.

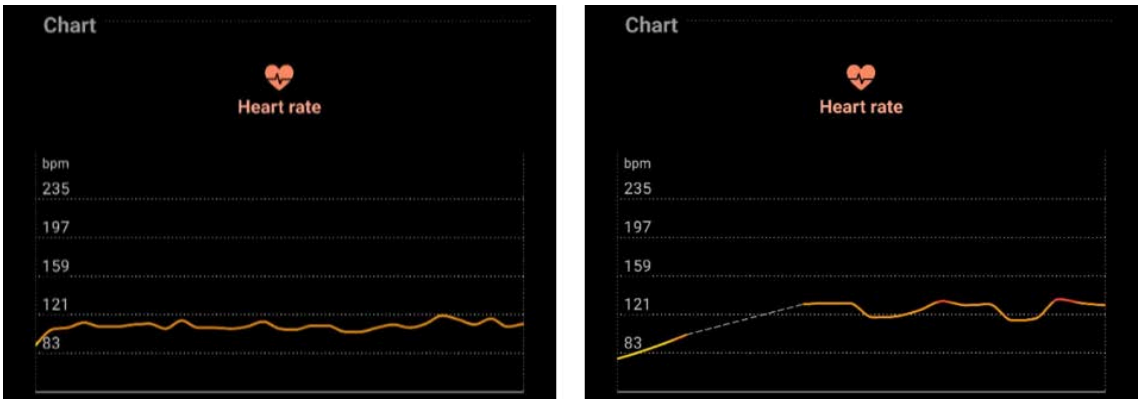


Figure 5.21 Participant heart beat data during both sessions on the left is with out the game and the right chart is with Spirit Overflow

(Samsung health app)

5.2.7 Discussion

This study aimed to design and develop an exercise game set up that could deliver an effective workout while generating an environment that could foster intrinsic motivation. The Qualitative results and interview, together with the heartbeat data, indicated that Spirit Overflow achieved this. The user reported a more immersive experience that engaged her physically and cognitively, resulting in better performance and a more effective workout.

Future iterations of the game, include multiplayer game modes and more bio-connection features to generate more emotional engagement with the characters.

The limitation is that the game is still a work in progress with some issues regarding bugs that sometimes make the game unstable. Also, the perception of the speed of the character was reported to be too slow, which slowed down the player's pace and immersion.

Chapter 6
Conclusion

Physical inactivity is one of the biggest problems concerning human health now and in the foreseeable future. With the emergence of COVID19 and people in the world been ask to be confined for long periods, the situation has worsened, leading to poor eating habits and even less physical activity.

The gym industry has suffered a hit by the economic crisis being forced to close locations and many failing for bankruptcy. Nonetheless, in-home exercise solutions have been on the rise, but with a growing population being physically inactive, we need more and different approaches to motivate people to move more.

Exergames, even though it is a growing field of research, it has proven to be promising in promoting positive aging. As technology evolves, new possibilities emerge from combining them to create innovative gaming experiences that can engage a broader audience.

Our research addresses the lack of physical training solutions that include game design into their concepts to create entertaining and beneficial systems. Spirit overflow is the result of a holistic approach to game design that combines in-home exercise hardware with a fitness-based adaptive exergame, opening the possibility of applying this concept to more in-home solutions.

Further, we plan to test the game with members of the sports and technology community and the general public to explore the capacity of the system to foster autonomous motivation to move.

Lastly, we arrived at several design considerations that could inform future exergame designs and helped this genre move forward as an effective solution to fight physical inactivity.

References

[1] World Health Organization et al. Global recommendations on physical activity for health. 2010, 2015.

[2] Physical Activity Guidelines Advisory Committee et al. Physical activity guidelines advisory committee report, 2008. *Washington, DC: US Department of Health and Human Services*, 2008:A1–H14, 2008.

[3] Harold W Kohl 3rd, Cora Lynn Craig, Estelle Victoria Lambert, Shigeru Inoue, Jasem Ramadan Alkandari, Grit Leetongin, Sonja Kahlmeier, Lancet Physical Activity Series Working Group, et al. The pandemic of physical inactivity: global action for public health. *The lancet*, 380(9838):294–305, 2012.

[4] who. Physical inactivity: A global public health problem. URL: `https://bit.ly/2Y6TSLN`.

[5] Steven N Blair, Michael J LaMonte, and Milton Z Nichaman. The evolution of physical activity recommendations: how much is enough? *The American journal of clinical nutrition*, 79(5):913S–920S, 2004.

[6] Pedro C Hallal, Lars Bo Andersen, Fiona C Bull, Regina Guthold, William Haskell, Ulf Ekelund, Lancet Physical Activity Series Working Group, et al. Global physical activity levels: surveillance progress, pitfalls, and prospects. *The lancet*, 380(9838):247–257, 2012.

[7] Grenita Hall, Deepika R Laddu, Shane A Phillips, Carl J Lavie, and Ross Arena. A tale of two pandemics: How will covid-19 and global trends in physical inactivity and sedentary behavior affect one another? *Progress in Cardiovascular Diseases*, 2020.

[8] Ana Jéssica Pinto, David W Dunstan, Neville Owen, Eloisa Bonfá, and Bruno Gualano. Combating physical inactivity during the covid-19 pandemic. *Nature Reviews Rheumatology*, pages 1–2, 2020.

[9] Albert Bandura. Human agency in social cognitive theory. *American psychologist*, 44(9):1175, 1989.

[10] Edward L Deci and Richard M Ryan. Self-determination theory. 2012.

[11] Pedro J Teixeira, Eliana V Carraça, David Markland, Marlene N Silva, and Richard M Ryan. Exercise, physical activity, and self-determination theory: a systematic review. *International journal of behavioral nutrition and physical activity*, 9(1):78, 2012.

[12] E Mullen, D Markland, and DK Ingledew. A graded conceptualization of self-determination in the regulation of exercise behavior: Development of a measure using confirmatory factor analysis. *Personality and Individual Differences*, 23(5):745–752, 1997.

[13] Eric Zimmerman. Narrative, interactivity, play, and games: Four naughty concepts in need of discipline, 2004.

[14] Jesper Juul. The game, the player, the world: Looking for a heart of gameness. *PLURAIS-Revista Multidisciplinar*, 1(2), 2018.

[15] Bernard Suits et al. The elements of sport. *Ethics in sport*, 2:9–19, 2007.

[16] Tom Wijmanl. The world ' s 2.7 billion gamers will spend 159.3 billion on games in 2020; the market will surpass 200 billion by 2023. `https://newzoo.com/insights/articles/newzoo-games-market-numbers-revenues-and-audience-2020-2023/`, May 2020.

[17] Katherine Isbister. *How games move us: Emotion by design*. Mit Press, 2016.

[18] James E Mazur. The matching law and quantifications related to premack's principle. *Journal of Experimental Psychology: Animal Behavior Processes*, 1(4):374, 1975.

[19] Jeff Sinclair, Philip Hingston, and Martin Masek. Considerations for the design of exergames. In *Proceedings of the 5th international conference on Computer graphics and interactive techniques in Australia and Southeast Asia*, pages 289–295, 2007.

[20] Mateus David Finco and Richard Wilhelm Maass. The history of exergames: promotion of exercise and active living through body interaction. In *2014 IEEE 3nd International Conference on Serious Games and Applications for Health (SeGAH)*, pages 1–6. IEEE, 2014.

[21] Josh Trout and Karra Zamora. Using dance dance revolution in physical education. *Teaching Elementary Physical Education*, 16(5):22–25, 2005.

[22] Bryan G Behrenshausen. Toward a (kin) aesthetic of video gaming: The case of dance dance revolution. *Games and Culture*, 2(4):335–354, 2007.

[23] Annika Kliem and Josef Wiemeyer. Comparison of a traditional and a video game based balance training program. *International Journal of Computer Science in Sport*, 9(2):80–91, 2010.

[24] Jan Sohnsmeyer, Hajo Gilbrich, and Burkhard Weisser. Effect of a six-week-intervention with an activity-promoting video game on isometric muscle strength in elderly subjects. *International Journal of Computer Science in Sport (International Association of Computer Science in Sport)*, 9(2), 2010.

[25] Leandra Abarca-Gómez, Ziad A Abdeen, Zargar Abdul Hamid, Niveen M Abu-Rmeileh, Benjamin Acosta-Cazares, Cecilia Acuin, Robert J Adams, Wichai Aekplakorn, Kaosar Afsana, Carlos A Aguilar-Salinas, et al. Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128· 9 million children, adolescents, and adults. *The Lancet*, 390(10113):2627–2642, 2017.

[26] Robert J. Vallerand. Deci and ryan's self-determination theory: A view from the hierarchical model of intrinsic and extrinsic motivation. *Psychological Inquiry*, 11(4):312–318, 2000. URL: `http://www.jstor.org/stable/1449629`.

[27] Philip M Wilson, W Todd Rogers, Wendy M Rodgers, and T Cameron Wild. The psychological need satisfaction in exercise scale. *Journal of Sport and Exercise Psychology*, 28(3):231–251, 2006.

[28] Edward L Deci and Richard M Ryan. The" what" and" why" of goal pursuits: Human needs and the self-determination of behavior. *Psychological inquiry*, 11(4):227–268, 2000.

[29] Edward L Deci and Richard M Ryan. Intrinsic motivation. *The corsini encyclopedia of psychology*, pages 1–2, 2010.

[30] Christina M Frederick and Richard M Ryan. Self-determination in sport: A review using cognitive evaluation theory. *International journal of sport psychology*, 1995.

[31] Geneviève Taylor, Tomas Jungert, Geneviève A Mageau, Kaspar Schattke, Helena Dedic, Steven Rosenfield, and Richard Koestner. A self-determination theory approach to predicting school achievement over time: The unique role of intrinsic motivation. *Contemporary Educational Psychology*, 39(4):342–358, 2014.

[32] Ed S Tan and Jeroen Jansz. The game experience. In *Product experience*, pages 531–556. Elsevier, 2008.

[33] Joyce LD Neys, Jeroen Jansz, and Ed SH Tan. Exploring persistence in gaming: The role of self-determination and social identity. *Computers in Human Behavior*, 37:196–209, 2014.

[34] Ben Lang. Beat saber ' has sold 2 million copies & 10 million songs for an estimated $67m. `https://www.roadtovr.com/beat-saber-2-million-units-sales-revenue/`, 2020.

[35] Ancret Szpak, Stefan Carlo Michalski, and Tobias Loetscher. Exergaming with beat saber: An investigation of virtual reality aftereffects. 2020.

[36] technogym. technogym website. `https://www.technogym.com/us/line/skillrow-class/`, 2020.

[37] Peloton. Peloton website. https://www.onepeloton.com/, 2020.

[38] Zwift. Zwift website. https://zwift.com/ja, 2020.

[39] Francesca Tosi. Ux evaluation of a new rowing ergometer: The case study of the technogym "skillrow". In *Advances in Usability, User Experience and Assistive Technology: Proceedings of the AHFE 2018 International Conferences on Usability & User Experience and Human Factors and Assistive Technology, Held on July 21–25, 2018, in Loews Sapphire Falls Resort at Universal Studios, Orlando, Florida, USA*, volume 794, page 233. Springer, 2018.

[40] Jeanne Nakamura and Mihaly Csikszentmihalyi. The concept of flow. In *Flow and the foundations of positive psychology*, pages 239–263. Springer, 2014.

[41] Valoclimb. Valoclimb website. https://valomotion.com/valoclimb/, 2016.

[42] Raine Kajastila, Leo Holsti, and Perttu Hämäläinen. The augmented climbing wall: High-exertion proximity interaction on a wall-sized interactive surface. In *Proceedings of the 2016 CHI conference on human factors in computing systems*, pages 758–769, 2016.

[43] Tim Brown et al. Design thinking. *Harvard business review*, 86(6):84, 2008.

[44] Konami Holding. Fy2019 financial results. https://img.konami.com/ir/en/ir-data/meeting/2019/en0509_7a46fa.pdf, May 2019.

[45] Jeffrey T Kullgren, Andrea B Troxel, George Loewenstein, David A Asch, Laurie A Norton, Lisa Wesby, Yuanyuan Tao, Jingsan Zhu, and Kevin G Volpp. Individual-versus group-based financial incentives for weight loss: a randomized, controlled trial. *Annals of internal medicine*, 158(7):505–514, 2013.

[46] Barbara J Speck and Joanne S Harrell. Maintaining regular physical activity in women: evidence to date. *Journal of Cardiovascular Nursing*, 18(4):282–293, 2003.

[47] Ian Anderson, Julie Maitland, Scott Sherwood, Louise Barkhuus, Matthew Chalmers, Malcolm Hall, Barry Brown, and Henk Muller. Shakra: tracking and sharing daily activity levels with unaugmented mobile phones. *Mobile networks and applications*, 12(2-3):185–199, 2007.

[48] Bob Heere. Embracing the sportification of society: Defining e-sports through a polymorphic view on sport. *Sport Management Review*, 21(1):21–24, 2018.

[49] super welfare expo. superwelfareexpo website. `http://www.peopledesign.or.jp/fukushi/`, 2019.

[50] superhuman sports. superhumansports website. `http://superhuman-sports.org/academy/eindex.html`, 2019.

[51] Maxplanck. Maxplanck website. https://www.cbs.mpg.de/en, 2020.

[52] jymmin. jymmin website. http://jymmin.com/, 2020.

[53] Jan Garrard, Chris Rissel, and Adrian Bauman. Health benefits of cycling. *City cycling*, 31, 2012.

[54] Polar. Polar website. "https://support.polar.com", 2020.

Appendices

A. Consent Waiver

By signing this document I give consent to the Kinix team, KMD students, to capture, store and analyze data during a user test experiment for the development of the kinix project.

Also, I am aware of the following:

- -There is video being taken.
- -There is EMG data being recorded.
- -The data is being recorded.
- -As a result of this data a software will be developed.
- -My participation in this study is as a volunteer and I have no authorship over the results of it.

Name and date

B. Intrinsic Motivation Gameplay Questionnaire

Name:

Age:

Please indicate how you felt while playing the game for each of the items, on the following scale:

- not at all = 0
- slightly = 1

- moderately = 2
- fairly = 3
- extremely = 4

1. Makes me feel that I need to complete things
2. Makes me strive to take myself to the next level of the world
3. Drives me to collect things if I am to progress
4. Inspires me to maintain my standards of my physical performance
5. Gives me the feeling that I need to reach goals
6. Makes me push my limits
7. Challenges me
8. Motivates me to do things that feel highly demanding
9. Makes me work at a level close to what I am capable of
10. Feels like a test of my physical ability
11. Inspires me to compete
12. Makes me strive to be the best
13. Gives me a sense of being directed
14. Gives me the feeling that I have an instructor
15. Gives me useful feedback so I can adapt
16. Makes me feel immersed
17. Makes me lose myself in what I am doing
18. Makes my actions seem to come automatically
19. Causes me to stop noticing when I get tired
20. Gives me an overall playful experience
21. Gives me a feeling that I want to know what comes next
22. Appeals to my curiosity
23. I thought it was fun
24. I thought it was boring
25. I would like to compete with someone else
26. I want share my results

Open questions:

Would you play it again? How likely would you be interested in unlocking new characters?

What new features would you implement to this game?

C. Ideation Workshop result

Cell evolution

eat, grow and evolve

#multiplayer #party #competetive
#customization #evolution #grow

game mode:
Free mode
Team mode
Battle Royale

spore/ agar io

Defender

defend waves of enemy with your friends

#multiplayer #co-o #wave defence
#shooter #diverse weapon #upgrade

bit blaster / yet another zombie defense hd

The Bumper squad

crash your enemy

#multiplayer #party #exciting
#violence #customizable #team work

game mode:
Conquest mode
Annihilation mode

Bumper car/ robot fight

Delivery man simulator

Delivery and destroy

#multiplayer #party #violence
#simulation #customization

Playing on bike: finish missions and gain money

Playing on mobile: build home and buy items(vehicles, decoration, cloth, skills)

thief simulator/the stretcher /totally reliable delivery service/ gta

Don't Stop the Line

don't stop assembling

#multiplayer #party #co-o

overcooked/ moving out/ tools up/ **Unrailed**

Slide to live

move or die

#mltiplayer #party #fast pace
paltformer

move or die

D. Intrinsic Motivation Inventory Questionnaire

Gender Age:

For each of the following statements, please indicate how true it is for you, using the following scale (1 to 7):

- not at all true = 1
- Very true = 7

1)This activity was fun to do.
2)I thought this was a boring activity.
3)This activity did not hold my attention at all.
4)I thought this activity was quite enjoyable.
5)I think I am pretty good at this activity.
6)After working at this activity for a while, I felt pretty competent.
7)I was pretty skilled at this activity.
8)This was an activity that I couldn't do very well.
9)I put a lot of effort into this.
10)I didn't put much energy into this.
11)I tried very hard on this activity.

12)I didn't try very hard to do well at this activity.

13)I believe this activity could be of some value to me.

14)I think that doing this activity is useful for exercising more

15)I believe doing this activity could be beneficial to me.

16)I think doing this activity could help me to improve my endurance

17)I think this is important to do because it can make people exercise during COVID19