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Pokyny pro vypracování

Cílem diplomové práce je navrhnout a následně vytvořit interaktivní fyzickou aplikaci pro interaktivní stěnu INITI Playground s cílem motivovat jednotlivce k fyzické aktivitě.

1) Proveďte rešerši v oblasti interaktivních stěn:
   a) aktivity dětí na hřištích a jejich přístup k hraní a učení,
   b) fyzické aktivity,
   c) gamifikace,
   d) návrhu uživatelského rozhraní pro interaktivní stěny.
2) Analyzujte stávající řešení.
3) Navrhněte a implementujte aplikaci pro interaktivní stěnu.
4) Proveďte vhodné testy.

Elektronicky schválil/a Ing. Michal Valenta, Ph.D. dne 28. února 2024 v Praze.

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Master's thesis

Interactive Walls: Bridging Play, Health, and Technology

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May 9, 2024

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Declaration

I hereby declare that the presented thesis is my own work and that I have cited all sources of information in accordance with the Guideline for adhering to ethical principles when elaborating an academic final thesis.

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Abstrakt

Táto diplomová práca skúma oblasť technológie interaktívnych stien, pričom začína prehľadom ich definície, prípadov použitia a analýzou existujúcich riešení. V ďalších kapitolách sa venuje konceptu aktívneho hrania, pričom rozlišuje medzi digitálnymi a nedigitálnymi hernými zážitkami. Diskusia sa rozširuje o úvahy o fyzickom zdraví v rôznych vekových skupinách vrátane detí až po starších ľudí spolu s metodikami merania a zvyšovania fyzického zdravia. Nasleduje komplexné preskúmanie gamifikácie, objasnenie princípov motivácie, zapojenia používateľov a "flow" stavu. Ďalšia kapitola skúma používateľské zážitky a návrh rozhrania s osobitným zameraním na jedinečné aspekty interaktívnych stien spolu s úvodnou diskusiou o nekalých praktikách. V záverečnej kapitole sa opisuje implementácia aplikácie fyzickej zdatnosti prispôsobenej špeciálne pre interaktívnu stenu INITI, pričom sa ponúkajú poznatky o tipoch na vývoj, výsledkoch testovania používateľov a možnostiach budúcich vylepšení.

Klíčová slova interaktivní stěna, hra, fyzické zdraví, gamifikace, uživatelské rozhraní, uživatelský zážitek

Abstract

This master's thesis explores the realm of interactive wall technology, beginning with an overview of its definition, use cases, and an analysis of existing solutions. Subsequent chapters delve into the concept of active play, distinguishing between digital and non digital play experiences. The discussion extends to physical health considerations across various age groups, including children to the elderly, along with methodologies for measuring and enhancing physical well-being. A comprehensive examination of gamification follows, elucidating principles of motivation, user engagement, and the attainment of flow states. User experience and interface design are then explored, with a particular focus on the unique considerations inherent in interactive wall interfaces, alongside an introductory discussion on dark patterns. The final chapter details the implementation of a physical fitness application tailored specifically for INITI interactive wall, offering insights into development tips, user testing outcomes, and avenues for future enhancements.

Keywords interactive wall, play, physical health, gamification, user interface, user experience

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Introduction

Interactive walls represent an emerging frontier in human-computer interaction, offering unique opportunities for engagement and exploration compared to other contemporary technologies. The primary objective of this thesis is to develop a fitness application tailored for interactive walls, specifically those provided by INITI playgrounds. However, achieving this goal necessitates a comprehensive understanding of theoretical underpinnings.

The initial chapter of this thesis will delve into the interactive wall landscape, with a focus on INITI playgrounds' offerings and it's competitors. It will explore the underlying technology behind these walls, including the wall structure itself and the sensors responsible for touch input detection. Additionally, real-world and potential use cases will be examined, alongside an analysis of existing interactive games and interactive scenes.

Subsequent chapters will address key topics such as child play and technology usage, exploring concepts like active play, the distinction between digital and non-digital play, and the perspective on it from children's view compared to adults. Moreover, the discussion will encompass the connection between play and flow state, as well as the identification of barriers to enjoyment, including intrapersonal, interpersonal, and environmental factors.

Subsequently, the discussion will pivot towards the realm of physical health, emphasizing the paramount importance of physical activity and cardiovascular fitness across all age demographics, from children to the elderly. This discourse will encompass the physiological implications of physical activity, its correlation with longevity, and methodologies for quantifying fitness levels.

Moving forward, the thesis will explore gamification, examining its definition and application in non-gaming contexts. Topics such as motivation, user engagement, flow theory, and competitiveness will be discussed, alongside an analysis of effective gamification elements such as leaderboards. Ethical considerations surrounding gamification will also be addressed.

The final theoretical chapter will focus on user interfaces and experiences, particularly in the context of large interactive walls and displays. This section will discuss interaction modalities unique to such environments, contrasting them with conventional interfaces found on smartphones and personal computers. Additionally, a brief overview of dark patterns will be provided to underscore ethical considerations in interface design.

Concluding the non-theoretical discourse, the subsequent chapter will transition into practical implementation, detailing the development of the fitness application. This section will include an introduction to the Unity game engine, its integration with INITI walls, practical implementation details including code snippets, insights from user testing, and future development prospects for the application.

Chapter 1

Interactive Wall

This chapter will be primarily dedicated to the INITI Playground Interactive Wall. It will explore its nature, functionality, use cases, and conduct an analysis of existing solutions, games, and applications developed for the wall. Additionally, the chapter will delve into potential future expansions and discuss how they could enhance the overall user experience. Given that INITI Playground does not operate in isolation within this domain, this work will also examine its competitors, facilitating comparisons between them.

According to the creators, the

> *"**INITI Playground** is an interactive platform designed to integrate virtual games into the real world. The platform encourages playful interactions, natural movement, and brings people together to socialize using game-like stories. The technology can transform any flat surface into a multi-touch area and turn it into a gaming stage of unlimited size, simultaneously engaging an unlimited number of players in front of our interactive walls."* [1]

Based on that statement, it is reasonable to infer that the wall aims to promote physical activity and reduce prolonged periods of sitting in front of computers. Additionally, the wall supports multiple touch inputs, fostering social interaction among its users. These assertions hold significance for further analysis, exploring use-cases, and considering implementation strategies.

1.1 Technology

The INITI Playground wall comprises three primary components: the wall itself, the touch sensor, and the media server. For the purpose of this thesis, auxiliary elements such as cables and wireless keyboards will not be explored in detail. The main emphasis of the discussion will centre around the touch sensor and the wall.

1.1.1 The Wall

The primary objective of the INITI Playground wall is to showcase content, presenting two distinct options for achieving this goal. The first option involves utilizing a dataprojector to display content on a physical wall, creating a real

and tangible viewing experience. Alternatively, the wall can be configured as a pixel-based display for superior viewing experience. Each of these options possesses its own set of advantages and disadvantages, contributing to the versatility and adaptability of the interactive platform.

The dataprojector offers the advantage of being flexible in terms of setup, as it can be placed anywhere there is a wall, presenting a significant benefit. However, the choice of projector type and its positioning introduces various considerations. Placing the projector behind or above the user provides easy mounting options, but it comes with the drawback that the user may block the light, rendering the content invisible when approaching the wall.

Short-throw projectors offer a solution to the occlusion issue, as the chances of the user obstructing the light are significantly reduced. However, this approach poses a higher risk of potential damage to the projector unit itself due to its proximity to users.

A third option involves siting the projector behind a translucent wall, ensuring the projector's safety from user interference. However, this approach requires additional space behind the wall and mandates the use of a translucent material for the wall itself. While this method protects the projector, there is a potential risk of damage to the wall, and the wall's translucency might impact its durability.

Each projector setup option presents a unique set of advantages and disadvantages, and the selection should be based on a careful evaluation that also takes into account the safety hazards associated with mounting the dataprojector.

The second option, involving the pixel display, is characterized by a somewhat constrained flexibility, as dedicated space is invariably required for installation, and the process of relocation proves inconvenient. An elevated risk of causing damage to the display panel is associated with this option, coupled with the inherent expense of the panels themselves. Additionally, a limitation arises from the current unavailability of sufficiently large-sized TVs or panels. Despite these challenges, the merits of this option include the absence of potential user occlusion of the content and a superior visual display technology, particularly notable in brightly lit environments, outpacing the capabilities of projectors.

Pixel based solutions come in three options [2]:

1. **LED Walls** possess the highest luminosity and visibility, making them well-suited for brightly lit environments. Typically composed of multiple panels, these walls address current technological limitations by circumventing the challenge of creating a single mother glass with limited pixels per inch. It's worth noting that this solution requires separate touch sensors for each panel, if INITI sensor is not used.

2. **Individual Multitouch Displays** offer the advantage of good luminosity, resolution, and built-in touch sensing capabilities. However, a notable limitation is the size restriction imposed by current technology, which typically allows displays to be created up to around 65 inches at the time of writing this thesis. Consequently, when considering interactive walls, it's not accurate to refer to individual multitouch displays as "walls" due to their size constraints.

3. **Multitouch Video Walls** represent a fusion of previous technologies, combining multiple smaller multitouch displays to form a cohesive wall. This solution may feature built-in touch capabilities in the displays themselves or be "retrofitted" with an infrared frame or a laser curtain. However, it's important to note that this solution is the most costly among the options available.

1.1.2 The Touch Sensor

The primary objective of the touch sensor is to detect user input on the wall, and there are several types of sensors that interactive walls can employ. The following list is not a comprehensive collection of all technologies but rather an example of how interactive walls can receive input from users.

- **Capacitive touch screens** measure changes in capacitance when a conductive object (such as a finger or stylus) comes into proximity with the sensor.
- **Resistive touch sensors** [3], including pressure sensors and force - sensing resistors, measure the amount of pressure applied by detecting the gap between two ITO layers or using principles such as amount of resistance, piezoelectricity, piezoresistivity, capacitance, or optics.
- **Infrared sensors** [4] encompass three types: those capable of measuring the amount of infrared light without interference from fingers, sensors that detect the deformation of the glass layer, and those utilising 3D Time of Flight cameras to measure distance. This method is known for its high durability, even in military settings.
- **Gesture recognition cameras** capture user movements and gestures, using computer vision algorithms to interpret these movements as commands. This enables hands-free interaction with the interactive wall, exemplified by technologies like Microsoft Kinect or Leap Motion.
- **Proximity sensors** [5], such as Lidar or laser curtains, utilise laser pulses to measure the time it takes for the pulses to return after bouncing off objects.

The INITI Playground wall utilises a lidar laser as its primary sensor. This sensor operates by employing a rotating laser at high speeds, continuously checking interception distances. Through these interceptions, the system can precisely determine the user's touch location on the wall. This solution offers the capability for multiple inputs with satisfactory accuracy.

This solution offers several advantages, including ease of mounting and low cost. The use of a single laser for input from multiple users contributes to the cost-effectiveness of the system. As mentioned earlier, the accuracy is deemed satisfactory; it can detect the interception of small objects. However, it's essential to note that the input is recorded within an approximate five-centimeter radius, as indicated by real life hands on tests. This limitation restricts the system from achieving super precise pinpoint accuracy.

The disadvantages of this solution include the necessity for precise and careful mounting of the touch sensor. Any tilt in its positioning must be avoided

to minimize the occurrence of false touch inputs stemming from uneven surfaces. Ensuring the touch sensor is mounted perpendicularly to the wall can enhance input responsiveness, consistently recording inputs at the same distance from the wall. Additionally, when the dataprojector is tampered with, new calibration of the sensor is needed for correct input.

While the system supports multiple inputs, a single sensor's vulnerability to occlusion poses a challenge. It's possible to obstruct the sensor, making inputs in the sensor's invisible region undetectable.

To address these challenges, employing two touch sensors may be a viable solution, effectively eliminating the issue of invisible regions. The introduction of a second sensor also brings an added advantage – the capability to detect not only the location but also the speed of the input. This enhancement opens up possibilities for more creative applications and functionalities.

Competitors in this area may utilise alternative methods for collecting touch information[1], distinct from lidar technology. Some may opt for an infrared sensor approach, as mentioned in [6], while others may incorporate cameras. These cameras can utilise either 3D technology, as indicated in [7], or pose detection and estimation techniques, as referenced in [8].

1.2 Use-Cases for Interactive Walls

This section will discuss the various use cases for interactive walls, focusing on their benefits and real-world examples, while omitting specific technology implementation requirements.

Interactive walls have diverse applications across various domains, including education, fitness, commercial use, corporate presentations, and productivity enhancement in workplaces. They can be found in a wide range of specific locations, including playgrounds, malls, museums, airports, arcades, aquariums, bouldering walls, and virtual try-on setups.

Investing in interactive wall technology offers numerous benefits across various domains. [9] In the commercial sector, interactive walls seamlessly integrate interactive technology with captivating visuals, establishing a memorable connection between brands and audiences. This heightened level of engagement promotes better information retention and leaves a lasting impression on viewers. Similarly, in educational settings and corporate presentations, where information retention is crucial, interactive walls prove invaluable.

In airports and malls, interactive walls serve as captivating art pieces or engaging time-wasters, thereby reducing negative emotions associated with waiting times. Additionally, in aquariums, interactive walls can provide a means to access detailed information about the various fish species residing within, enhancing the visitor experience.

Another crucial benefit is the promotion of increased social interaction, addressing a growing concern in modern society where many technologies tend to isolate individuals and contribute to decreased attention spans. This issue is particularly pertinent from early childhood, a topic that will be further discussed in the next chapter, along with the benefits to our physical health.

[1] It's essential to note that information regarding input sensing should be approached with caution, as we lack direct access to the cited products and rely on estimated guesses based on information available on their websites.

And now, let us delve into real-world exemplars:

- **INITI Playground** has successfully deployed interactive walls [10] in various prestigious locations like EXPO 2020 Dubai or Siggraph Conference L.A [11]. along with museums such as the National Museum in Prague. There, children engage with educational games using foam balls, fostering an immersive learning experience. Additionally, INITI Playground installations can be found in galleries like the Moravian Gallery and the Slovak National Gallery, where visitors interact with art pieces in innovative ways. These installations showcase a diverse array of interactive applications, exemplifying the versatility and engagement potential of interactive wall technology.

- **Clothing stores**, exemplified by brands like Tommy Hilfiger, harness the power of interactive walls to captivate passersby [12]. By integrating motion recognition cameras, these walls dynamically dress pedestrians in the latest apparel sold within the store, offering a virtual try-on experience. This innovative approach not only captures attention but also engages potential customers, enticing them to explore the store's offerings in a novel and interactive manner.

- **Incheon Airport** has ingeniously transformed one of its lounges into a virtual gym [13], seamlessly blending interactive walls with tangible elements such as trampolines and baskets. This innovative fusion of virtual and physical components creates an immersive experience where users feel deeply immersed in the game. By summing up the total height of trampoline jumps or the number of balls successfully fit into the hoop, users strive to achieve high scores, adding an exciting dimension to their airport experience.

- **Nike's Unlimited Stadium** is a unique 200-meter track field [14], intricately designed in the shape of an infinity symbol. Along this track is an interactive wall that meticulously records each runner's progress and compares their performance to that of other runners, akin to the way racing games display ghost cars. This innovative setup not only provides runners with real-time feedback but also fosters a competitive atmosphere, motivating them to push their limits and achieve their personal best.

- **TeamLab**, particularly their Koi and People artwork [15], elevates the concept of interactive walls by shifting the focus from walls to floors. In this installation, the floor is flooded with water to shin height, serving as the canvas for projected Koi fishes. These virtual Koi fishes dynamically gather around individuals and disappear upon being touched, creating a mesmerizing and immersive experience that blurs the boundaries between art and audience interaction.

Certainly, while there are numerous real-world examples of interactive wall deployment, the uses mentioned above succinctly encapsulate the diverse range of applications for interactive walls. From basic functionalities to more creatively artistic showcases, these examples showcase the versatility and potential of interactive wall technology in various domains and settings.

1.3 Analysis of Existing Solutions

In this section, an analysis[2] of existing solutions will be conducted along with applications that are still in development, these games are:

1. **Demons I** is a Western-themed game featuring animated demon characters that spawn randomly for players to defeat. The scene is fully interactive, with features such as lamps that turn on and off, windows that break, and cans that fall over. The graphics are well-made and visually appealing. However, the visibility of demon characters is sometimes low, making it difficult for players to identify them, especially amidst all the clutter that can spawn. Fortunately, this does not significantly impact the experience, as the game is more of an interactive scene than a traditional game. Additionally, it must be activated by the operator of the media server, not by the users themselves. Overall, "Demons I" stands out as the best option from the basic bundle due to its plethora of interactive elements.

2. **Builders from Mars** is a game where players strive to prevent alien developers from taking over the city. Unlike the previous game, this one is a true game in which players must actively destroy buildings by clicking on the hearts within the building blocks. Failure to destroy the buildings results in a game over state if they become too large. Although it features fewer interactive elements compared to the previous game, most of them do not significantly enhance the gameplay. Nonetheless, it remains an enjoyable game and deserving of second place.

3. **Save the planet!** is a cooperative space-themed game with the goal of defending the planet. Serving as a spiritual successor to Space Invaders, enemies attack from two sides, supplemented by meteor strikes and aliens that disable Earth's defenses. Despite its enjoyable premise, this game ranks as the least favorable of the three. Its simplistic mechanics allow players to easily complete it by merely holding their hand in one place, as enemies will fly into harm's way. However, it still offers a fun experience and is worth trying out.

4. **Spaceship Shenanigans** is one of the most fully developed, yet still in development, games. Its main gameplay loop involves completing small tasks or mini-games, similar to the popular video game Among Us. Designed for multi-person interaction, the tasks are mostly self-explanatory and easy to complete. The game boasts impressive 3D graphics and overall quality. However, a notable drawback is the small and closely spaced buttons, which can lead to accidentally pressing multiple buttons at once. Fortunately, this issue has been addressed in the sequel, which, while not yet graphically finished, offers improved input handling.

5. **No Quiet on the Front** is an engaging castle defense game currently in development. Players spawn units to destroy the opponent's castle by throwing balls at the wall to hit units on a "conveyor belt." Despite

[2] personal opinions of the author of this thesis

its simpler graphics, the game exudes charm and offers an enjoyable experience. While the balance may be slightly off, exploring its unique mechanics is definitely worth the opportunity.

6. **Karneval** is a game in development where players engage in various carnival-themed minigames, such as basketball, aligning pipes for water flow, popping balloons, and hitting targets. Despite being a work in progress, it offers a fun experience, especially for multiple players competing against each other.

7. **Ducks** serves as a spiritual successor to the classic duck hunt game. While it offers support for multiple users, the game's visual clarity and overall appeal are lacking. Despite this, its chaotic nature may still appeal to children.

8. **Malování** is an early-stage painting application that allows users to paint, but it faces limitations such as low sample rates, making smooth lines impossible. Additionally, UI elements suffer from poor visibility due to contrast issues with the data projector.

9. **Point** is a personal trainer game intended to assess perception and reaction time. Unfortunately, it was not available for testing, serving as the primary competitor for the application developed in this thesis.

10. **Golden Fish (floor ver.)** is a game that casts players in the role of a fisherman attempting to catch a golden fish to fulfill their wishes. Regrettably, it was not available for testing.

In general, every game or experience is worth trying despite some of their shortcomings. However, the fun factor is currently limited, mainly due to frustrating input handling and lack of precision, as well as the repetitive nature shared by all games.

1.4 Conclusion

This chapter has explored the concept of interactive walls, discussing their display and input technologies, examining various use cases and benefits across different domains, and analyzing existing solutions, including multiple games and experiences. From the research, it's evident that interactive walls hold promising potential for education, marketing, and user engagement, but their success relies on offering innovative experiences beyond touch or throw games. Enhancements like an additional lidar sensor and motion tracking technologies could further improve INITI Playground and facilitate future application development.

Chapter 2

Child Play and Technology Usage

This chapter will explain what active play is, how digital and non-digital play differ, how different parties see the difference and how is play connected to flow theory and what are the implications and dangers. It will also include what could stop children from participating in active play and what the ideal environment looks like.

2.1 Digital vs Non-Digital Play

Exploring the concept of play for children is crucial in understanding the implications of digital versus non-digital play and its impact on learning, social skills, motor movement, and healthy technology habits. This discussion is particularly relevant when considering the educational or recreational use of interactive walls, as promotional videos from the previous chapter have highlighted children as the primary users of these walls. Therefore, delving into the nuances of play and its effects on child development will provide valuable insights for the design and implementation of interactive wall experiences aimed at children.

Firstly, play of any kind is crucial for kids' healthy development, as it provides children with opportunities to make sense of their worlds and fosters knowledge of social and cultural practices and values.

Secondly, digital play encompasses any form of play that involves digital or electronic devices, while non-digital play does not incorporate them. Non-digital play ranges from playing with dolls, building with Legos, and drawing to engaging in active play, which is the focus of our discussion due to its relevance to the resources found. Importantly, children do not necessarily perceive digital play and non-digital play as distinct categories [16]; they seamlessly transition between them. It is acknowledged by children that learning through play and digital play is now a normal and embedded part of everyday life for young children.

The choice of digital over non-digital play is often influenced by the power of digital content to attract and hold attention. Reports indicate that children frequently opt to engage with screens over other activities, and once engaged, they may struggle to disengage from their devices to transition to other experiences. That is why it's important to help children with digital well-being, self-regulation, safe technology use, and balanced engagement with devices, be-

cause digital life and real life are becoming less distinct, and subsequently, for many younger children, digital play is just play.

In exploring healthy digital well-being habits, it becomes evident that four key elements intertwine to shape children's interactions with technology:

1. **Immersion and Engagement with Technology**: This encompasses both traditional and digital forms of play, along with the intrinsic elements of play itself.

2. **Flow and Play**: Understanding the immersive nature of play and addressing associated concerns.

3. **Children's Agency in Play**: Examining how digital citizenship intertwines with well-being, highlighting the pivotal role of children in directing their play experiences.

4. **Supports Needed**: Recognizing the importance of guidance from adults or knowledgeable peers in nurturing children's development, particularly in cultivating concrete thinking.

With that being said, technology can afford new types of play, but it is often assimilated into and alongside more traditional play and learning. For example, school-aged kids may perceive their study time with iPads as play, while teachers see it as learning. This highlights the differing perceptions between children and adults regarding what constitutes play and what constitutes learning. Whether the resources are physical or digital, the guidance and support received from educators is more important than the actual tools in developing children's concrete thinking, which is connected to point number four. Additionally, it was found [17] that a female instructor is slightly preferred compared to other options like a superhero or a puppet, when it comes to guidance.

Delving deeper into the first element, it's imperative to understand the fundamental aspects that define play and contribute to knowledge acquisition:

- **Enjoyable**: Play is inherently enjoyable, providing individuals with pleasure and amusement.

- **Sense of awareness** that it is different from everyday life: During play, individuals possess an awareness that the activity is distinct from their usual daily experiences.

- **Symbolic in nature** and sometimes only understood by the person playing.

- **Child-led**: Play is typically initiated and guided by children themselves, reflecting their interests and preferences.

- **Voluntary**: Participation in play is voluntary, with individuals willingly choosing to engage in the activity.

- **Rules are accepted freely** and respected as binding.

- **Able to control and direct actions**.

- **Process-based**, focusing entirely on the activity rather than on an end product or achievement.
- **Intrinsic motivation**: Play is driven by intrinsic motivations, with individuals engaging in the activity for the sheer enjoyment and satisfaction it brings.
- **Immersed in activity** and less conscious of self and time.

There are parallels between the characteristics of the flow state by Csikszentmihalyi and the characteristics of play-based learning. The flow state is defined as *"the state in which people are so involved in an activity that nothing else seems to matter; the experience itself is so enjoyable that people will do it even at great cost, for the sheer sake of doing it."* [18] In this state of highest involvement, deep-level learning takes place. However, this state can also induce the formation of habits and, therefore, has the potential to trigger addictions.

Table 2.1: The eight elements of flow compared to characteristics of play.

Elements Of Play	**Flow State**
Enjoyable	Balance between challenge and skills
Sense of awareness	Able to ignore irrelevant external content
Play is voluntary, child-led, able to control and direct actions, rules are accepted freely	Sense of control over the activity
Certain rules or limitations	Clear sense of what needs to be done moment by moment
Process based, intristic motivation	Intristically rewarding - doing it for its own sake
Intrisic motivation, process based	Intense concentration of attention
Active - involves interaction with other people, resources or the surrounding environment	Immediate feedback on how well one is doing
Less concious of self and time	Distortion of sense of time

And because of the addictive factor, it is important to develop games or apps with responsibility, as there could be connections between habit formation and rewards. For instance, offering additional benefits as a subscriber or allowing players to gather credits or rewards throughout gameplay to purchase items within the game can lead to games that are no longer intrinsically motivating in the way that play is usually considered to be, but rather extrinsically motivated by the rewards on offer. These topics will be further explored in sections about gamification and dark patterns in user interfaces.

2.2 Active Play

Active play [19] refers to a diverse range of unstructured, spontaneous physical activities and behaviors in which children engage. For example, these can

include digging, raking, lifting and carrying, exploring, planting, chasing, and pushing objects into positions; they involve construction, imagination, and creativity. This type of play improves classroom behavior, helps develop social, cognitive, and physical skills, and promotes psychological well-being by fostering intrinsic motivation, competence, and a sense of belonging.

This type of play could be implemented into school curriculums, as children spend most of their weekdays, more than thirty hours a week, in schools, making them an obvious and suitable setting for active play. Active play on school playgrounds makes up to 50 percent of children's recommended daily physical activity, which gives children the chance to build active, healthy bodies and to develop their decision-making, negotiating, and motor skills.

Other studies have found that the older children are, the more likely they are to be sedentary and less likely they are to engage in vigorous active play. That's why it's important to design experiences in which children and even adults would participate willingly. However, to do that, it's important to understand why someone would not participate in such activities. Findings point to three main influences:

1. Intrapersonal
2. Interpersonal
3. Environmental

Intrapersonal influences on children's active play involve an individual's knowledge, behavior, attitudes, and skills, where age, sex, and body mass index[3] are the most commonly measured influences on children's play. Investigators have found that gender is the most common demographic variable that correlates with children's active play, with males being correlated with greater active play. Boys are typically more active, competitive, and require fewer social interactions, while girls may need more space to socialize. Therefore, activities and experiences should be tailored accordingly.

Regarding weight and BMI, studies present contradictory findings. Some suggest that non-overweight children engage in significantly more active play, while overweight children engage in significantly less. However, a New Zealand self-reporting study found that overweight or obese children are 27 percent more likely to engage in active play than non-overweight children, with no association found between BMI and activity levels.

Additionally, many children lack even the basic skills to engage in active play, feel embarrassed to participate, and may face bullying. Therefore, fostering self-efficacy, fun, enjoyment, and skill improvement, as well as promoting less competitive and more social forms of active play for girls, is essential for intrapersonal motivation for children to engage in active play.

Interpersonal influences include relationships, culture, and social factors, which have a major impact on children's active play. These factors are particularly important due to the social nature of interactive walls. As mentioned previously, studies have identified peer and teacher support as positive correlates to children's active play. Additionally, further studies have found that

[3] BMI

children consider play partners and social acceptance as key factors influencing their engagement in active play.

Regarding socioeconomic status, studies have yielded mixed results depending on the country, with some finding significant correlations and others not. However, bullying has emerged as a major barrier to children's active play. This may include instances of weight shaming or equipment theft. Another barrier is the presence of a large number of people already playing or the absence of a partner with whom children can participate. These interpersonal factors significantly influence children's engagement in active play.

Environmental influences include where the play takes place, the materials used, and the equipment provided. Positive effects were observed when playgrounds were located in outdoor facilities such as sporting courts and grassy areas. However, mixed or inconclusive results were found for sporting fields, watery areas, woods, and soccer fields. Surprisingly [19], the introduction of movable or recycled materials into play had a significantly positive effect, increasing positive social inclusion, resilience, and teamwork among children. Metal structures were also better received than wooden ones. Furthermore, substantial equipment yielded better results, although preferences varied depending on the age of the children. While movable equipment is preferable for some, others still prefer fixed structures.

The size of the play area is also controversial and depends on socioeconomic status. Children from more affluent families believed playgrounds were small and lacked space, whereas children from less privileged schools were satisfied with the available play area. This suggests that the ideal playground would feature ample greenery and trees, include movable recycled equipment and sturdy metallic structures, and provide enough space for engagement without becoming overcrowded. Additionally, school uniforms were found to have a negative influence on play, particularly among girls. Engagement significantly increased when they were allowed to wear different attire for play.

And last but not least, physical activity benefits young children's development in terms of cognitive and brain development, executive function, as well as reducing anxiety and depression. As mentioned earlier, 50 percent of the daily recommended activity occurs during active play. Research has also found that children are generally more active on playgrounds than during physical education classes, although they engage in higher-intensity activity during classes. This imbalance can be addressed by increasing the time children are allowed to spend on the playground and the frequency of breaks, resulting in higher-intensity activity. The importance of this will be covered in the next section.

Chapter 3

Physical Health

In this chapter, the importance of physical activity, cardiovascular fitness, and muscle strength will be discussed across all age ranges, spanning from children and young adolescents to adults and the elderly. Also recommended amounts of physical activity, predictors of longevity and health benefits will be explained.

3.1 Origins

Physical activity has always been recognized as crucial for maintaining a healthy body, mind, and longer life, a belief held by ancient Greek physicians such as Herodicus, Hippocrates, and Galen. They emphasized that a healthy body was a prerequisite for mental well-being.

In the 18th century, physicians like Bernardino Ramazzini, considered the father of occupational medicine, observed that professional messengers, many of whom were exceptional runners, avoided hazards common to sedentary occupations. Even Benjamin Franklin advocated for physical activity, recommending 15 minutes of brisk stair climbing at intervals throughout the day, along with swimming and dumbbells. Thomas Jefferson similarly emphasized the importance of exercise, stating, "Not less than two hours a day should be devoted to exercise, and the weather shall be little regarded. If the body is feeble, the mind will not be strong."

Today, it is widely accepted that higher levels of physical activity and cardiorespiratory fitness are associated with better health outcomes. However, despite this knowledge, current physical activity patterns are undeniably at their lowest in human history [20], likely due to sedentary jobs, long commutes, and increased screen time, with predictions indicating a worsening trend.

3.2 Physical Health in Children and Youth

To counteract this trend, let's continue from the previous section where it was mentioned that physical activity offers numerous benefits for children and young adults across various aspects of development. Early adulthood is a phase characterized by considerable plasticity in the central nervous system, during which important cognitive traits are shaped. Brain plasticity refers

to the brain's ability to adapt to new situations, environments, or the consequences of injury. Cardiovascular fitness, as an indicator of physical exercise, strongly influences brain plasticity, improving memory function and structural parameters such as synapse density, neuronal complexity, and hippocampal neurogenesis[4].

Voluntary running significantly restores the neural stem cell pool, hippocampal neurogenesis, and behavioral deficits following clinically relevant, moderate doses of irradiation. However, there are conflicting data concerning the effects of physical exercise on memory and cognition in young individuals. Although aspects of delayed long-term memory improve, and there is a slight effect on reaction time in young people, some studies suggest that physical exercise has little impact on overall memory and cognition.

A Swedish study of men born between 1950 and 1976, involving more than a million subjects, determined that cardiovascular fitness at age 18 is associated with cognitive performance. Conversely, muscular strength showed a weak association, significant only for lower scores.

From the figures shown in 3.1, it appears that aerobic capacity was most strongly associated with logic and verbal intelligence. These findings indicate that changes in cardiovascular fitness are linked to changes in cognitive performance during adolescence. Better cardiovascular fitness at age 18 years was associated with higher educational attainment, with a greater magnitude observed for occupational outcomes. This suggests that changes in physical achievement between ages 15 and 18 years predict cognitive performance at age 18 years and socioeconomic status and educational attainment later in life during early adulthood.

These findings [22] support the notion that cardiovascular exercise improves cognition through increased levels of circulating factors that positively influence brain plasticity and cognitive function. However, it's important to note that only male subjects were analyzed in this study, which may limit the generalizability of the results. Furthermore, while increased cardiovascular fitness between ages 15 and 18 years exhibited significantly greater intelligence scores than subjects with decreased cardiovascular fitness[5], and predicted occupational status and educational achievement later in life, direct causality cannot be established.

Other studies [23] suggest that encouraging children to increase their levels of physical activity may help reduce their current blood pressure, which is likely to track into adulthood and contribute to reducing their total cardiovascular risk. Additionally, it was found that cardiorespiratory fitness levels, whether moderate or high, are associated with significantly lower metabolic syndrome prevalence in adolescents. This implies that physical activity and cardiorespiratory fitness are positively related to a healthier cardiovascular risk profile in youth.

The present study [22] also determined a high heritability for cardiovascular fitness, indicating that factors other than heredity and upbringing are important contributors to the association. Referring back to the previous sec-

[4] a remarkable form of brain structural plasticity [21] by which new functional neurons are generated from adult neural stem cells/precursors

[5] three groups were defined based on cardiovascular fitness at age 18 years: the "increased" group, comprising the 90th percentile; the "decreased" group, comprising the 10th percentile; and the "unchanged" group, representing the 10th to 90th percentile

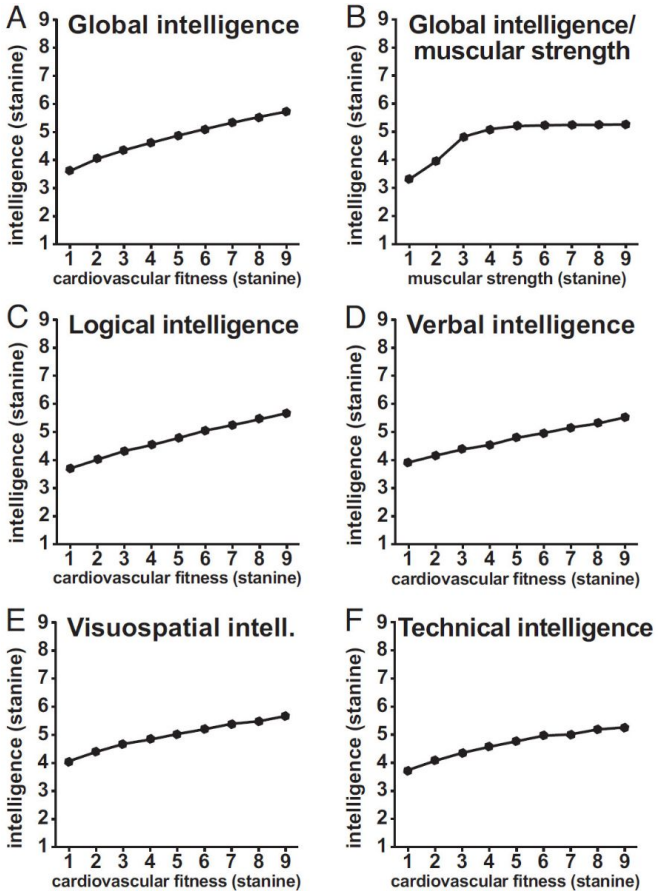


Figure 3.1: Mean levels of intelligence stanine scores by cardiovascular fitness or muscular strength at age 18 y.o. [22]

tion on interpersonal influences, active parents tended to raise active children; therefore, encouraging activity among parents may help children to be active.

3.3 Physical Health in Adults and the Elderly

And on the topic of parents and adults, let's shift to benefits of exercise to this age group. Physical activity during midlife appears to protect against dementia and to improve cognitive performance in older adults with memory impairment, leading to increased longevity with a significant reduction of morbidity [24] and mortality[6].

In elderly subjects, a positive association between cardiovascular fitness and cognitive performance is observed [22], along with increased hippocampal volume and better memory function.

[6]Morbidity is the state of being unhealthy for a particular disease or situation, whereas mortality is the number of deaths that occur in a population.

3.4 Fitness Measures and Health Outcomes

Higher cardiorespiratory fitness and physical activity patterns offer various benefits across all age ranges, contributing to the prevention of not only cardiovascular diseases but also specific cancers, type 2 diabetes mellitus, improved bone health, reduced disability, increased longevity, and decreased non-cardiovascular-related mortality. These benefits are observed regardless of race or gender and apply to individuals with documented cardiovascular disease as well. The reduction in mortality risk per 1-MET[7] increase in exercise capacity ranges between 10 percent and 25 percent in both men and women. Recent evidence from cardiac magnetic resonance imaging studies suggests that higher levels of physical activity are associated with more favorable cardiac structure and function, and higher physical activity attenuates mortality risks associated with obesity. Specifically, cardiovascular mortality was 62 percent higher for women who were obese and inactive compared to obese women who were active. Overall, these studies [20] provide compelling evidence that cardiovascular disease risk is substantially higher, ranging from 35 to 90 percent, for obese individuals who are physically inactive compared to their obese counterparts who are active. However, the interaction between obesity and physical activity in influencing morbidity from cardiovascular disease is more complex and is also dependent on factors such as fat distribution over the body, such as waist circumference compared to hip girth.

Another great measure of cardiorespiratory fitness is maximal oxygen uptake VO_2max, where one MET corresponds to an oxygen uptake of $3.5mL/kg$ per minute. Individuals with low VO_2max ($< 27.6mL/kg$ per minute) were associated with a 2.76-fold[8] risk of overall mortality after adjusting for age, examination years, smoking, and alcohol consumption. The best way to improve VO_2max is through high-intensity exercise rather than low-intensity, but it is sufficient to say that even low intensity has positive health benefits, especially in high-risk persons. However, some studies suggest that the volume of activity may be more important than the intensity. [23] Maximal oxygen uptake usually decreases by 5 to 15 percent per decade between the ages of 20 and 80 years, and the rate of decline in oxygen uptake is directly related to the maintenance of physical activity level [25], emphasizing the importance of physical activity.

Heart rate recovery, the speed at which the heart returns to its resting beats per minute after intensive physical activity, has been identified as a significant indicator of physical health and mortality [26]. Quicker recovery times, indicating a faster return to baseline heart rate, have been associated with decreased all-cause mortality rates compared to individuals with abnormal recovery times. This measurement provides valuable insights into cardiovascular health and underscores the importance of efficient heart rate recovery in promoting overall well-being and longevity.

While some earlier studies did not establish a clear correlation between muscle strength and mortality, recent research [27] provides compelling evidence that muscle strength is indeed predictive of longevity, irrespective of other potential negative health factors. Specifically, high muscle strength has been shown to prolong a person's life, regardless of other metabolic considerations.

[7] MET - metabolic equivalent, testing with peak MET levels achieved

[8] $95\%CI, 1.43 - 5.33, P = 0.002$

Grip strength is often used as a measure of overall strength. Individuals with stronger grip strength exhibit a 34 percent lower risk of mortality compared to those with weaker grip strength. Additionally, for every 5-kilogram decrease in grip strength among men, there was a corresponding 16 percent increase in the likelihood of all-cause mortality.

Another unexpected result emerged from the study, which found a link not only to physical activity and muscle strength but also to balance [28]. Despite limitations related to uncontrolled variables such as recent history of falls and physical activity, the ability to successfully complete the 10-second One-Leg Stand test is independently associated with all-cause mortality. This finding adds relevant prognostic information beyond age, sex, and several other anthropometric and clinical variables.

Sadly, physical activity alone may not be sufficient for weight management. Burning 500 calories per day requires almost one hour of moderate-intensity exercise. Therefore, in addition to physical activity, dietary adjustments are often necessary to combat obesity. It's important to note that approximately 7700 calories are equivalent to one kilogram of body fat. [20]

3.5 Recommended Amount of Physical Activity

Moderate amounts of exercise can lead to significant health benefits. Some studies suggest that even a 5 to 10 minute jog per day can lower mortality risk, demonstrating that daily physical activity can substantially improve health and quality of life. This is particularly important in combating the sedentary lifestyle, which is associated with higher overall healthcare costs and is estimated to account for 12 percent of all deaths in the United States and around 11.7 percent in developed countries. Even as little as 3-minute sessions of moderate physical activity have been shown to reduce mortality risk. It's evident that exercise acts as a form of medicine, and it's time for this premise to be universally accepted. [20] Other studies support the recommendation [25] that every adult in the United States should accumulate at least 30 minutes or more of moderate-intensity physical activity on most, preferably all, days of the week to promote health and prevent chronic diseases.

Even though small amounts of physical exercise can be beneficial for health, recent research suggests increasing the duration [29]. The newest research paper[9] recommends at least 150 minutes of moderate-intensity aerobic exercise per week, or 75 minutes of vigorous activity, or a combination of both.

- Participants who met the guidelines for vigorous physical activity had an overall 19 percent lower risk of death from all causes.
- Participants who met the guidelines for moderate physical activity had an overall 20-21 percent lower risk of death from all causes.
- Participants who performed two to four times above the recommended amount of long-term vigorous physical activity (150-300 min/week) had an overall 21-23 percent lower risk of death from all causes.

[9] At the time of writing this thesis.

- Participants who performed two to four times above the recommended amount of moderate physical activity (300-600 min/week) had an overall 26-31 percent lower risk of mortality from all causes.

Cardiorespiratory fitness has been shown [20] to be at least as effective as statin therapy in lowering mortality risk. However, physical activity continues to be overlooked and underutilized as an intervention to reduce the risk of cardiovascular diseases, all-cause mortality, and other outcomes. Several factors contribute to this underutilization. Firstly, the implementation of plans to increase physical activity must involve various stakeholders, including healthcare providers, the industry, health insurance companies, government agencies, the public, and more. Additionally, time constraints and other competing priorities may hinder individuals from engaging in regular physical activity. These challenges highlight the need for comprehensive strategies and collaborative efforts to promote physical activity as a crucial component of overall health and disease prevention.

Chapter 4

Gamification

Gamification is defined as the use of game design elements in non-game contexts such as work environments, marketing, politics, health, and fitness to encourage and motivate users [30]. Game design elements include star ratings, progress bars, levels of increasing difficulty, badges for completing tasks, feedback mechanisms, goals, leaderboards, and user levels. The concept of gamification gained popularity around 2010, and since then, over 70% of Global 2000 companies have implemented at least one gamified application.

This section will delve into gamification, exploring its impact on motivation and user engagement, its connection to flow theory, its application in fitness apps, strategies for implementation, and the key elements to consider. Additionally, the section will conclude with a brief overview of the ethical considerations surrounding gamification.

4.1 Motivation

For repetitive and monotonous tasks, gamification can be particularly beneficial because playful experiences help make non-game scenarios more motivating and engaging.

Meaningful gamification considers the intrinsic motivation of users and leads to better user engagement in the long run [31]. Intrinsic motivators exist within all of us, driving desires for improvement, achievement, autonomy, and connection with others. However, users are motivated differently, and what may motivate one person can demotivate another [32].

Motivation can be categorised into extrinsic motivation, which results from external factors such as rewards, and intrinsic motivation, which arises from internal factors such as satisfaction [33]. Amotivation, on the other hand, refers to a lack of motivation. According to Self-Determination Theory, basic psychological needs must be met to motivate individuals both intrinsically and extrinsically: autonomy, the need to feel in control; competence, the need for progress; and relatedness, the need to connect with others.

To achieve intrinsic motivation, all three needs must be satisfied, while extrinsic motivation requires at least competence and relatedness to be addressed. Intrinsic motivation also involves the concept of purpose, where actions hold meaning for the individual undertaking them. While gamification shows promise in motivating users, it is not always the case.

4.2 User Engagement

User engagement is a critical determinant of the success or failure of any software application. Even with basic gamification elements that bring fun and enjoyment, if not appropriately designed, they may not significantly increase user engagement. However, gamification is just one component influencing user engagement. Other factors include utility, interactivity, social networking, and personalization.

Gamification can be categorised into two main types: reward-based gamification and meaningful gamification. Reward-based gamification, while initially effective, may not sustain user engagement in the long run. In contrast, meaningful gamification, which taps into intrinsic user motivation, tends to be more efficacious. Nevertheless, reward-based gamification can incorporate other elements to enhance user engagement over time. For instance, methods such as personalization can be integrated into reward-based gamification strategies to bolster long-term engagement. Social networking features also play a crucial role in increasing user engagement, allowing users to create personal profiles and connect with other users within the application.

Utility is another crucial factor for successful user engagement. Recent studies [31] have underscored the importance of addressing human needs and expectations for application success. Without meeting user needs and expectations, applications lack utility, thereby diminishing user engagement. In such cases, gamification or other engagement methods may prove ineffective in boosting user engagement .

Interactivity is essential for enhancing user engagement in software applications. Various interactive features, such as scrolling, zooming, tapping, clicking, and dragging, can enrich the user experience and increase engagement.

Furthermore, personalization empowers users to customise the look and feel of the application based on their preferences. By considering user preferences, interests, and intrinsic motivations, gamification can foster increased user engagement over the long term.

4.3 Gamification and Flow Theory

Flow theory, previously discussed in section 2 within the context of child play and technology usage, is now examined from a gamification perspective.

For gamification, the PAT model is proposed, which separates the artifact from the task and consists of three factors: person, artifact, and task. Educators embarking on gamification learning should consider these dimensions as a guide to motivate learners to enter the flow state.

Setting clear goals for learners is crucial. Providing learners with clear and unambiguous goals stimulates expectations and cultivates a "Goal-Oriented Mindset." Goal theories suggest that learner motivation stems from their own perception of the goal, emphasizing the central role of goals in motivation theory. In gamification learning, providing learners with goals containing clear learning content stimulates internal motivation, establishes a positive psychological state, and lays the foundation for learners to enter the flow state.

Table 4.1: Elements of stimulating flow experience in gamification learning based on the PAT model. [34]

Aspect	Key Elements
Person	Age of learners Cognitive characteristics of learners Learner's emotions during learning
Artifact	Genre and cognitive characteristics Interact way of game Interactive strategy of the game
Task	Learning content analysis Learning objective analysis Task and learner matching degree analysis Difficulty ladder setting

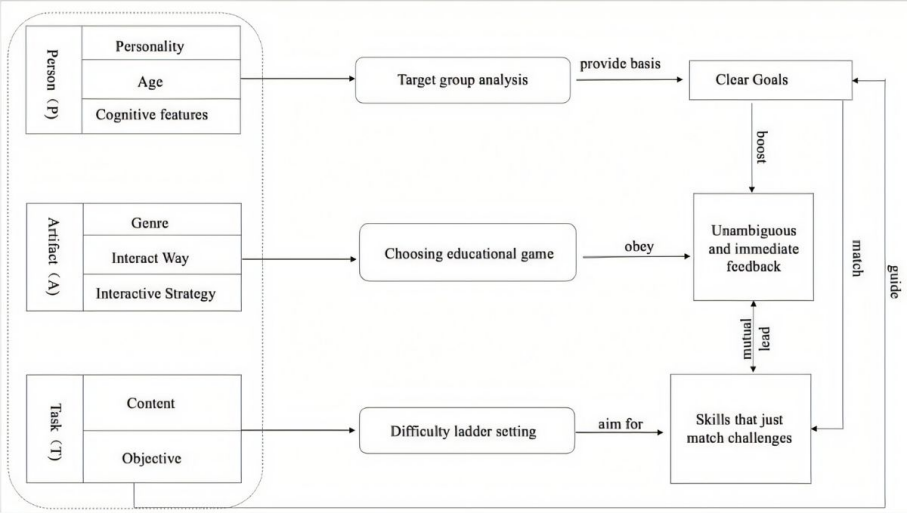


Figure 4.1: Gamification learning model based on flow theory. [34]

Providing learners with unambiguous and immediate feedback is crucial. Feedback is essential for improving learning effectiveness, as educators offering specific and timely feedback help learners enhance self-awareness and regulate their learning behaviors. Feedback elicits both positive and negative emotions. Timely feedback on the learner's outcomes can stimulate positive emotions and motivate learners to work towards their current learning goals, facilitating entry into the flow state. Conversely, delayed feedback can lead to learner resistance, fostering negative emotions and hindering entry into the flow state.

Ensuring skills match challenges appropriately is crucial in gamification. When participants feel they are not competent enough to complete a challenge, they may experience anxiety. Conversely, if they feel overly competent, they may become bored. The essence of gaming lies in players not having

full control. Games with dynamic difficulty adjustment techniques that detect learners' level of development in real-time are recommended. Therefore, it is essential to analyze both the content and objectives, as well as the learner's existing capacities. Only by accurately measuring these aspects can a balance between skills and challenges be achieved, allowing for dynamic adjustment of difficulty levels.

Understanding the relationships between the three antecedents of flow is crucial [34]. Firstly, "clear goals" can facilitate the creation of "unambiguous and immediate feedback". Secondly, "unambiguous and immediate feedback" and "skills that just match challenges" are mutually reinforcing. Finally, "skills that just match challenges" need to be aligned with "clear goals".

4.4 Strategies for Implementation

Applying gamification to systems to enhance system usage enjoyment requires thoughtful design.

The effectiveness of gamification hinges on identifying the application's utility [31]. Gamification goals should be established based on the overall utility of the application and the problems it solves for users. Designers must determine how to employ challenges, exploration, control, and progress to achieve their gamification objectives. Consequently, designers can select the types of user interactions needed to accomplish gamification tasks and allocate appropriate rewards for each action.

Designers interested in gamification should ponder the following questions:

- What systems and processes should be gamified?
- What user behaviour is desired?
- What game elements should be incorporated?
- What kind of rewards will be given to the users?

When considering desired behavior and game elements, designers can refer to a framework [30] that delineates three aspects of gamification design:

- **Mechanics**: Game components related to data representation and algorithms, such as points and badges.
- **Dynamics**: Runtime behavior of mechanics pertaining to players, including completion and choices.
- **Aesthetics**: The emotional responses intended to be evoked in players while interacting with a gamified system, such as feelings of challenge and community.

The 5W2H+M framework [33] stands out as one of the most comprehensive approaches to gamification design, offering a user-centered, generic, flexible, and broad perspective that addresses core gamification principles. However, it may lack detailed guidance on fostering a motivational environment.

This framework comprises the following components:

- **Who?** Identifies the users of the system.
- **What?** Specifies the behaviors that the target audience should exhibit while using the system.
- **Why?** Determines the stimuli that will encourage users to perform the desired tasks.
- **When?** Identifies the appropriate situations in which users should be stimulated to exhibit the desired behavior.
- **How?** Guides the selection of game elements to be implemented in the system to generate stimuli.
- **Where?** Determines where prototypes and implementations will be developed.
- **How Much?** Evaluates the effectiveness of gamification in stimulating users.

It's crucial to avoid reducing gamification to mere pointifications [30]. Additionally, considerations of privacy and ethics are paramount, as electronic monitoring and surveillance often accompany gamification implementations.

A successful gamification implementation is one that maximizes the expected business objectives defined by designers. It is important to note that the positive effects of gamification can decrease when the novelty has worn off.

The one-size-fits-all approach means that engagement and playfulness levels achieved from them are sub-optimal and possibly even negative. [35] Users' personalities affect how they perceive gamification; explorers find hidden items by exploring systems' different areas, whereas achievers complete as many challenges as possible. Designers should be cautious in providing monetary or other concrete rewards. Additionally, gamification might induce unwanted behavior if game elements become more important than the core functions and if the gamified elements distract users from the task's main purpose. This distraction can lead to a decrease in the quality of the work task and a decrease in productivity. Productivity will also likely decrease if users feel disadvantaged due to other users cheating the system.

4.5 Leaderboards as Gamification Elements

Previous research has highlighted that the primary reason games are enjoyable is their ability to provide fantasies, evoke curiosity, and present challenges to players [36]. Consequently, a crucial aspect of a game is its capacity to generate challenges, a function often enhanced by fostering comparison and competition among players. Leaderboards serve this purpose effectively by emphasizing comparison and fostering immediate competition, distinguishing them from other gamification elements like levels and badges.

However, leaderboards still have various issues in their use. Application designers must find ways to motivate every user, not just the top performers, and keep users in different positions engaged even if they have fallen behind [35].

While leaderboards were mostly positive in increasing motivation, engagement, and enjoyment, their impact varies in competitive versus non-competitive environments. Individuals with specific personalities may find them playful in one situation and non-playful in another. Furthermore, the competitive social condition may not always make a significant difference, indicating gaps in our understanding of how leaderboards affect individuals' psychological and behavioral responses, especially in the health and fitness context.

Social comparison theory delves into the inherent human tendency to assess oneself by comparing with others. This process aids individuals in evaluating their own performance, particularly when objective information for self-assessment is lacking. Social comparison involves acquiring information about others to gauge one's opinions and behaviors, leading to either upward or downward comparisons across various dimensions such as status, capabilities, and achievements. The direction of comparison yields different emotional responses: upward comparison may signal opportunities for improvement or feelings of inferiority, while downward comparison may evoke reassurance or complacency about one's current standing.

Environmental factors significantly influence the social comparison process, particularly in contexts like fitness apps where leaderboards foster competition among users. Moreover, facilitating conditions, encompassing both social support and favorable physical environments, play a pivotal role. Perceived control and self-efficacy serve as key moderators in social comparison studies, influencing individuals' attitudes and behaviors. Research [36] suggests that users' attitudes positively impact their physical activity behavior, with perceived competitive climates enhancing the relationship between social comparison and attitude. Conversely, self-efficacy regarding physical activity tends to mitigate the relationship between social comparison and attitude.

Additionally, a study [37] suggested allocating points upfront and deducting them if goals are not met, aiming to increase engagement and reduce motivation fatigue. Another study [38] conducted in Croatia compared two groups of students using gamification, with one group receiving point rewards. The results indicated that the reward system positively influenced student motivation, satisfaction, and engagement with course activities throughout the semester, highlighting the importance of extrinsic motivation in gamification.

4.6 Kano Model and Gamification Elements

The Kano model categorizes requirements into five distinct quality classifications [39], each playing a crucial role in shaping user satisfaction and experience:

- **Attractive** (Excitement Needs): These are unexpected or innovative features that have the potential to delight players and create a memorable experience. In gamification, this could include surprise rewards, Easter eggs, social interactions, storytelling elements, and immersive experiences. While not essential for basic functionality, these features can significantly enhance engagement and enjoyment.

- **One-Dimensional** (Performance Needs): These are features that directly correlate with player satisfaction. In gamification, this could in-

clude elements like increasing difficulty levels, rewards for completing tasks, leaderboards, and progress bars. Meeting these needs can lead to increased engagement and motivation.

- **Must-Haves** (Basic Needs): These are the fundamental features or elements that players expect to be present in a game. In gamification, this could include basic functionality such as clear goals, progress tracking, feedback mechanisms, and a sense of achievement. Failing to meet these basic needs can result in dissatisfaction and a lack of engagemen

- **Indifferent Needs** (Indifferent): These are features that neither significantly increase nor decrease satisfaction when present or absent. In gamification, this could include neutral elements such as background music, cosmetic customization options, or minor animations. While they may add to the overall experience, they are not critical for player engagement.

- **Reverse Needs** (Must-Not-Haves): These are features that, if present, can actually decrease satisfaction. In gamification, this could include intrusive advertisements, overly complicated mechanics, or excessive penalties for failure. Avoiding these features is essential to maintain a positive player experience.

Figure 4.2: Result of the Kano model Classification. [39]

The study and research findings [39] suggest that the progress path dimension, along with the feedback and reward dimensions, are closely correlated and contribute positively to user satisfaction due to their elements' quality classification. Meanwhile, elements in the social connection dimension and interface and user experience dimension play an average role. As a result, gamification elements classified as must-have quality elements should be prioritized first, followed by one-dimensional quality elements, with particular attention given to attractive elements. Conversely, indifferent quality elements should be carefully considered before implementation.

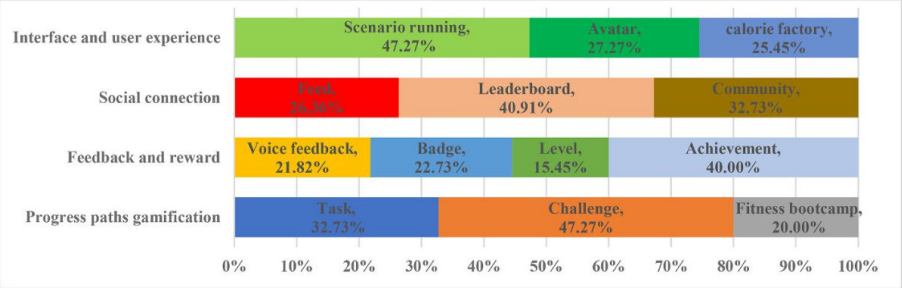


Figure 4.3: Popularity of elements. [39]

4.7 Gamification in Health and Fitness Applications

As previously discussed, parents (and teachers) play a significant role in shaping family health through their own physical activity behavior and role modeling. Through conviction and actions such as providing feedback, motivation, creating structures, and offering encouragement, parents have the most substantial influence on children's sense of joy and competence. Therefore, to enhance physical activity within families, attention must be directed towards parental figures [40]. However, it's widely recognized that the majority of fitness app users are young adults and students, who are less influenced by their parents' physical activity. Social factors [36], on the other hand, have been identified as predictors for the sustained use of physical exercise applications and the intention to recommend these apps to others.

Interestingly, only 16.3% of those surveyed [40], who currently do not meet the WHO reference values, expressed a desire to join a sports club or gym. What's notable is that the majority (80.2%) of respondents did not adhere to WHO recommendations but still perceived their health to be good. However, 50.2% of those not meeting WHO recommendations considered improving their health to be highly important. They expressed readiness to engage in health promotion activities by increasing physical activity, endurance, fitness, mobility, and performance, adopting a more active lifestyle with outdoor activities. Surprisingly, memberships and gymnastic training had the least impact, suggesting they may not be suitable for family sports.

The gamification elements that prove most beneficial for individuals already meeting the WHO reference values include coupling the app with trackers, ranking/high scores, collecting points with the family, and sharing and comparing achieved goals with others.

Here's the list of gamification elements commonly used in fitness applications, ranked from most used to least used [41]: *Goals, social influences, challenges, collaboration, competition, high scores, badges, narrative, streaks, points, levels, unlockable content, lifelines.*

According to other studies [42], game elements can be categorized into two types: **commensurate game elements**, such as points, which directly correlate with consumers' performance in a task, and **incommensurate game elements**, such as likes, which are not related to their performances. The study suggests that applications incorporating incommensurate game elements can effectively increase consumer engagement.

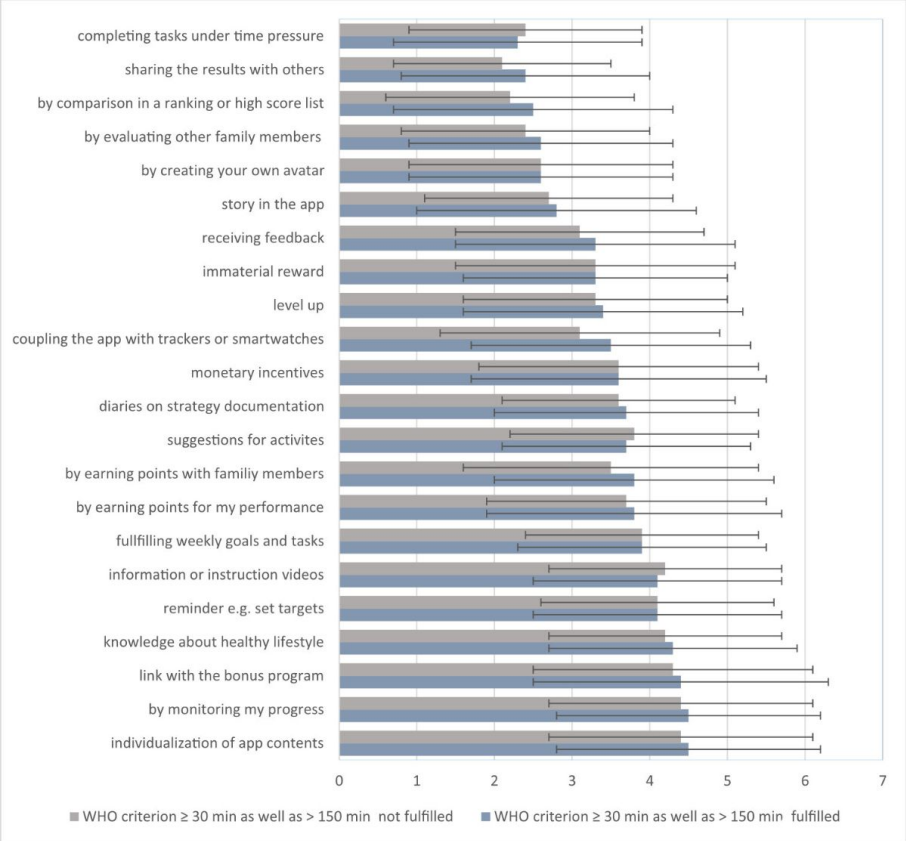


Figure 4.4: Interest in gamification elements as a function of the WHO recommendations fulfilled/not fulfilled. [40]

The study [42] primarily examined two fitness applications, WeRun and Walkup. WeRun focused on satisfying psychological needs and employed more incommensurate elements, while Walkup prioritized providing external incentives to performance and utilized more commensurate elements. Users of WeRun, which offered more incommensurate elements, exhibited higher intrinsic motivation in using the fitness app compared to those using Walkup. Additionally, they demonstrated higher levels of autonomy, achieved higher average daily step counts, and showed greater loyalty and support towards the fitness app.

When evaluating the impact of gamification on fitness applications and the industry, the benefits far outweigh the drawbacks. **Positive effect of gamification** on fitness and healthiness include [43]:

- Incorporating Gamification into physical exercise positively affects efficiency, effectiveness, and participant satisfaction.

- Exposure to gameful design elements increases enjoyment, satisfaction, and motivation.

- It promotes physical activities and social interaction and combats loneliness among older adults.
- Competitive and cooperative approaches to Gamification generate appreciation and sociality.
- It increases training intensity and experience in exergame-based functional high-intensity interval training.
- It reduces sedentary behaviors among students.
- People use more health apps because they have longer attention spans and are more engaged.
- It develops practical knowledge of users as gamification elements help them learn to develop patterns.
- Gamification can promote physical activity and improve health.
- By addressing some of the typical issues with conventional rehabilitation techniques, Gamification has the potential to be a useful tool in musculoskeletal rehabilitation.
- It can effectively promote intrinsic motivation and engagement in older adults.
- Gamification can make physical activity more exciting and enjoyable for employees and create a healthier workforce.
- Gamified elements can effectively motivate users to increase their fitness and productivity within organizations.
- A gamification-based strategy may be useful for encouraging physical activity and raising C.R.F. among college students.
- It can counteract the often-decreasing long-term motivation of health-app users.
- Gamified fitness apps can predict user preference according to user data

Negative effects of gamification on fitness and healthiness include:

- Participants may view exergaming as entertainment rather than exercise, thus reducing their activeness.
- It overreliance on extrinsic motivators.
- Some users may find the competitive nature of elements demotivating or stressful.
- It may lead to a focus on short-term goals rather than long-term behavior change.
- It may lead to an over-emphasis on competition, adversely affecting mental health.

Table 4.2: Categorisation of commensurate and incommensurate game elements.

Types of game elements	**Definition**
Commensurate game elements	The game element that the effort required in attaining which is directly associated with consumers' performance in a task.
Examples of commensurate game elements	• Badges: Element indicating achievements • Points: Numerical element indicating achievements • Progression: Milestones indicating progress of a task • Digital rewards: Virtual incentives, prizes, gifts
Incommensurate game elements	The game elements that the effort required in attaining which is not directly associated with consumers' performance in a task.
Examples of incommensurate game elements	• Role: Character or avatar performing task • Leaderboard: Ranks for comparison of task performance • Likes: Social recognition by other people performing a certain task

And **challenges of using gemification** include:

- Recruiting participants and ensuring compliance with the gamification intervention.
- Access to technology and digital literacy to participate in gamification interventions.
- Some users may not respond positively to Gamification in certain contexts or with certain activities. For example, according to, participants rated leaderboards least favourably in social networking contexts.
- Ethical issues related to Gamification in health and fitness tracking include privacy concerns, data security, and user autonomy.
- The relationship between an intervention's behaviour change technique content and the resulting health behaviour change is not simple and requires more study.
- The fully mediating role of I.T. identity is necessary for gamified designs to encourage meaningful interactions with the apps.
- There are some challenges in designing effective gamification strategies that appeal to both male and female users.
- Physical limitations may hinder participation in gamification interventions.
- Aesthetics in Gamification needs improvement, with realistic graphic visual and sound effects that provide more fun to users by creating aesthetically pleasing environments with sensory stimulation that are not at the required levels.
- There is a challenge in implementing Gamification in physical activity applications.
- Gamified fitness apps may not be suitable for older adults due to usability concerns such as font size, colour contrast, and navigation through the apps.

4.8 Ethics

In the realm of health, gamification aims to influence user behavior by promoting increased physical activity and the adoption of healthier lifestyles through engaging game-like experiences. Ethics, within the domain of philosophy, concerns the systematization, defense, and advocacy of principles governing right and wrong conduct. The ethical evaluation of gamification practices primarily hinges on the extent to which they:

1. Are exploitative,
2. are manipulative,
3. are intentionally or unintentionally harmful to the parties involved,
4. have a socially unacceptable level of negative effect on the character of the parties involved.

It is contended that gamification can be exploitative, particularly in situations where it unfairly disadvantages one party. Given that gamification fundamentally aims to induce behavioral change, it is inherently susceptible to the accusation of manipulation. This manipulation or exploitation arises from the conflict between the distinct sets of norms governing "the real world" and the "game world".

A classic illustration of the negative impact of incentivizing good behavior is akin to a parent offering candy to influence their child's actions.

Consider the scenario of a gamified health application aimed at encouraging users to exercise more. Suppose the app tracks user activity, shares it with their social network friends, and rewards them digitally for surpassing their peers. If the social network allows third parties, like data brokers, to extract this data, it could lead to privacy concerns for the user. In this case, it's challenging to argue that the designer is exploiting the user directly. However, the user may still experience harm due to the unequal power dynamic between the designer and the user. This stems from the designer's sole control over the app's design and data-sharing policies.

One could envision a scenario where a user becomes excessively fixated on the game elements of a health app, such as in-game rewards, even if the designer did not intend for this to occur. There are more aspects to consider, but delving into them exceeds the scope of this diploma thesis and its practical component. For further insights, refer to this paper [44].

4.9 Conclusion

Research [37] findings suggest that gamification generally produces positive outcomes, although its effectiveness greatly depends on how and where it's implemented, as well as the level of user engagement. While many studies demonstrate beneficial results, it's important to acknowledge potential drawbacks like increased competition. However, the overarching evidence indicates that gamification is indeed effective.

Chapter 5

User Interface and Experience

This chapter will take a closer look at what user interface and experience is, how they differ, and why are they intertwined together. It will also discuss what are the challenges, when designing interfaces for interactive walls and what are some of the shady tactics used by designers to make users do what they want.

5.1 User Interface

The user interface[10] has been defined in various ways by different authors. Here are few of those definitions:

> *"UI encompasses the interaction between users and systems, incorporating elements such as commands, graphics, appearance, content, and more. It serves as the graphical representation of the layout structure. UIs can vary in format, size, and platform, spanning from personal computers (PCs) and mobile phones to games, blogs, and beyond."* – Goel [45]

> *"The concept of UI design revolves around presenting users with the most important information and delivering content with high complexity through the most concise interface possible."* – Yua [46]

> *"UI design, also referred to as user interface, is crafted with users in mind, serving as the medium for information interaction between users and the system."* – Yua [46]

The goal and purpose of a user interface are straightforward: to bridge the gap between the user and the computer while offering users a visually pleasing experience that enhances their comfort and enjoyment [47]. However, achieving this goal is no easy feat. Selecting an appropriate design principle for the application is challenging, given the plethora of choices available. These include minimalism, flat design, gradient design, grids, matte glass, font-centric design, brutalism, 3D, animated design, parallax, and many more. Each option brings its own set of considerations and complexities to the design process.

[10] UI

Some argue that *"Style is the soul of the interface, layout is the skeleton of the interface, then color is the blood of the interface, injecting vitality into its veins."* [46]

General principles for creating user interfaces are fundamental to the design and implementation of all effective interfaces. Adhering to these principles is essential for achieving a good user interface. These principles include:

1. **Aesthetics:** The interface should be visually appealing.
2. **Clarity:** Information should be presented clearly and understandably.
3. **Compatibility:** The interface should work seamlessly across different devices and platforms.
4. **Comprehensibility:** Users should be able to easily understand the interface.
5. **Configurability:** Users should have the ability to customize the interface to suit their preferences.
6. **Consistency:** Elements should behave consistently throughout the interface.
7. **Control:** Users should feel in control of their interactions with the interface.
8. **Directness:** Interaction with the interface should be straightforward and intuitive.
9. **Efficiency:** The interface should facilitate efficient completion of tasks.
10. **Familiarity:** The interface should leverage familiar patterns and conventions.
11. **Flexibility:** Users should have options for different ways of interacting with the interface.
12. **Forgiveness:** The interface should be forgiving of user errors.
13. **Predictability:** Users should be able to predict the outcome of their actions.
14. **Recovery:** The interface should provide mechanisms for recovering from errors.
15. **Responsiveness:** The interface should respond promptly to user actions.
16. **Simplicity:** The interface should be kept simple and free from unnecessary complexity.
17. **Groupings and Focus:** Related elements should be grouped together, and focus should be directed towards important elements.
18. **Emphasis:** Important elements should be emphasized to draw attention.

While many of these principles are self-explanatory from their names, a deeper explanation of each principle is outside the scope of this thesis. For further information, refer to the cited paper [48].

For the purpose of this thesis and its practical implementation, as well as considering the preferences of the developer, the ideal design should be simple, minimalist, easy to read from both close up and a distance, uncluttered, and suitable for fitness applications. These requirements are effectively met by both flat and minimalist design approaches. Therefore, a combination of flat and minimalist design principles has been selected. In the following sections, we will delve into the specifics of this design choice.

Flat design is an approach to interface design that emphasizes simplicity and minimalism. It has been adopted and reformed by major players such as Microsoft, Google, and Apple. The essence of flat design lies in providing users with a fresh experience by eliminating complex textures and lifelike elements, thus reducing visual fatigue [46]. This design language advocates for minimalist presentation, facilitating direct and effective content output. Complex touches like icon stereoscopy, textures, highlights, and projections are eliminated in flat design. Ultimately, the aesthetic of flat design aligns with the need for a good user experience in UI design.

5.2 User Experience

User Experience[11], similar to UI, has been defined by numerous authors from various backgrounds, including both industry and academia. Here are a few of these definitions:

> *"A person's perceptions and responses that result from the use and/or anticipated use of a product, system or service."* – P. Ketola [49]

> *"All the aspects of how people use an interactive product: the way it feels in their hands, how well they understand how it works, how they feel about it while they are using it, how well it serves their purposes, and how well it fits into the entire context in which they are using it."* – L. Alben [49]

> *"A term that describes user's feelings towards a specific product, system, or object during and after interacting with it. Various aspects influence the feelings, such as user's expectations, the conditions in which the interaction takes place and the system's ability to serve user's current needs."* – V. Roto [49]

The absence of a universal definition of user experience can be attributed to several factors:

- **Dynamic Concepts**: User experience is associated with a wide range of dynamic concepts, including emotional, affective, experiential, hedonic, and aesthetic variables. The inclusion or exclusion of specific variables often appears arbitrary and depends heavily on the author's background and interests.

[11] UX

- **Unit of Analysis**: The unit of analysis for user experience is highly flexible. It can range from focusing on a single aspect of an individual end-user's interaction with a standalone application to considering multiple end-users' interactions with a company and its integrated services from various disciplines.
- **Fragmentation and Complexity**: The field of UX research is fragmented and complex, with diverse theoretical models focusing on different aspects such as pragmatism, beauty, affect, experience, value, pleasure, emotion, and hedonic quality. This fragmentation adds to the complexity of defining user experience in a universally agreed-upon manner.

These factors contribute to the multitude of definitions of user experience, reflecting the interdisciplinary nature of the field and the diverse perspectives and priorities of researchers and practitioners within it. Nevertheless, there are many critical uses of a UX definition, which tries to develop one meaningful in order to:

- Facilitate and ease scientific communication (e.g. between researchers with different backgrounds and from different disciplines).
- Help managing useful and practical applications of UX (e.g. operationalization and evaluation against measurements).
- Support the teaching of the concept and idea of UX with the basic understanding of its scope as well as its nature.

Table 5.1: Different Perspectives of User Experience. [49]

Perspective	**Description**
UX as a phenomenon	Describing what UX is and what it is not Identifying the different types of UX Explaining the circumstances and consequences of UX
UX as a field of study	Studying the phenomenon (e.g. how experiences are formed or what a person experiences, expects to experience, or has experienced) Finding the means to design systems that enable particular UXs Investigating and developing UX design and assessment methods
UX as a practice	Envisioning UX (e.g. as part of a design practice) Representing UX (e.g. building a prototype to demonstrate and communicate the desired UX to others) Evaluating UX Delivering designs aimed at enabling a certain UX

User experience along with its different aspects (e.g. pragmatic and hedonic) varies according to a number of factors: Individual, Product, Situation and Time.

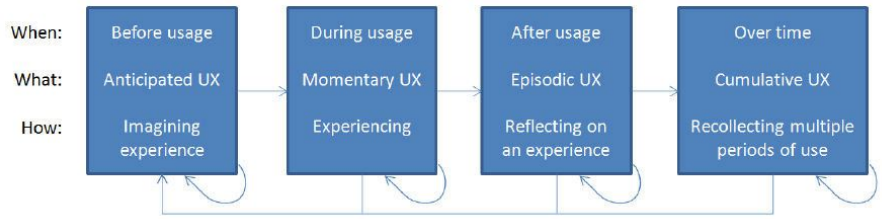


Figure 5.1: Time spans of user experience. [49]

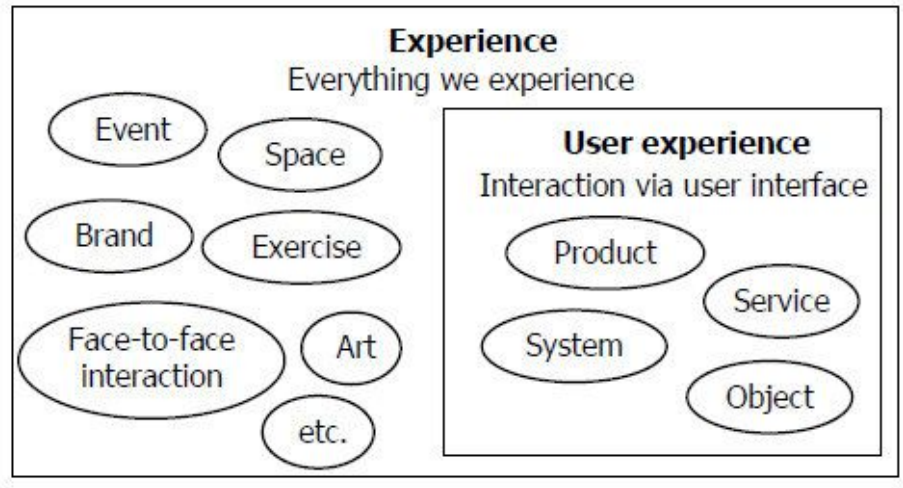


Figure 5.2: User Experience in relation to other experiences. [49]

It is crucial to recognize that the relationship between user experience and usability is interwoven and inseparable, although they differ in certain aspects. Usability tests primarily focus on task performance, whereas user experience encompasses lived experiences beyond mere task completion. User experience is inherently subjective, and therefore, objective usability metrics such as task execution time, number of clicks, or error rates are insufficient measures for capturing the entirety of user experience.

And why is user experience so important? Studies [50] show that experiential purchases (i.e., the acquisition of an event to live through, such as a concert, a dinner, a journey) make people more happy than material purchases (i.e., the acquisition of tangible objects, such as clothing, jewellery, stereo equipment) of the same value. This is the challenge we face: Experience or User Experience is not about technology, industrial design, or interfaces. It is about creating a meaningful experience through a device.

For example, the German Telekom made “experiencing” its marketing claim (“Erleben, was verbindet”). The companion website promises to be a place for sharing memorable and unique experiences. But a close look reveals hardly more than the occasional sponsored live event interspersed with badly disguised attempts to sell standard products and services. Experience is considered a

Category	Evaluation Method	Brief Description
Study type	Field studies	Field studies are conducted in naturalistic settings, real contexts of use. Can be short-term (i.e. an hour) or long-term (i.e. 2 weeks).
	Lab studies	Laboratory studies are conducted in fixed locations (i.e. usability labs, meeting rooms).
	Online studies	Online studies are done via Internet. Participants can be anonymous or invited.
	Questionnaires / Scales	Questionnaires or scales can be used in various different types of UX studies such as experiential aspects.
Development phase	Scenarios, sketches; (i.e. concepts)	Important decisions affecting user experience are done in the early phases of product development, when the concept ideas are discussed. It is not possible to let participants really interact with the system, but the material may include storyboards, moodboards, scenarios, or design sketches.
	Early prototypes	Early prototypes may be interaction flow sketches on paper, Flash prototypes on a computer, or early version of the actual system with the core functionality. Early prototypes often include the core functions only, participants cannot freely explore the system but they are typically given tasks to evaluate.
	Functional prototypes	Functional prototypes provide most of the planned functionality and can be given for participants to test freely.
	Products on market	When evaluating products on market from UX perspective, researchers can approach people who have actually used the system from their free will. Considered the best setup for evaluating user experience. Also participants can be users who have not used the product before.
Studied period of experience	Before usage	Evaluate participants' perception of the system before they have interacted with it. The material for evaluation may include sketches or 3D models of industrial designs, graphics, storyboards, scenarios, etc.
	Snapshots during interaction	Evaluate momentary experiences while the participant is interacting with the system.
	An experience (of a task or activity)	Investigate an experience with a specific begin and an end. These methods can be used to find out how participants feel about the system after executing a task or after using the system for some activity.
	Long-term UX	Study user experience over a longer period use than one test session only. Examples of these methods include long-term field studies, retrospective evaluation sessions, and questionnaires.
Evaluator / Information provider	UX experts	Utilize the knowledge of user experience professionals in evaluating UX of the system. Compared to user studies, expert evaluation is often easier to arrange. Experts can also evaluate "difficult" material such as product specifications or early prototypes with many technical problems. Basic problems can be avoided by conducting an expert evaluation before a more expensive user study.
	One user at a time	Investigate the experience of a single user by using, for example, interview, questionnaire, or psycho physiological measurement methods.
	Groups of users	When the focus of the user experience study is on social aspects, it is interesting to study participants as a group instead of single participants.
	Pairs of users	Compared to discussions with a researcher, discussions with a friend may reveal very different perspective of user experience.

Figure 5.3: User Experience Evaluation Methods. [49]

vehicle for marketing, but not understood as the very product that is sold.

Experiences can be summarized in a conceptual model with three different

levels: The Why, What and How.

- **The What** addresses the things people can do through an interactive product.
- **The How** addresses acting through an object on an operational, sensory-motor level
- **The Why** tries to clarify the needs and emotions involved in an activity, the meaning, the experience.

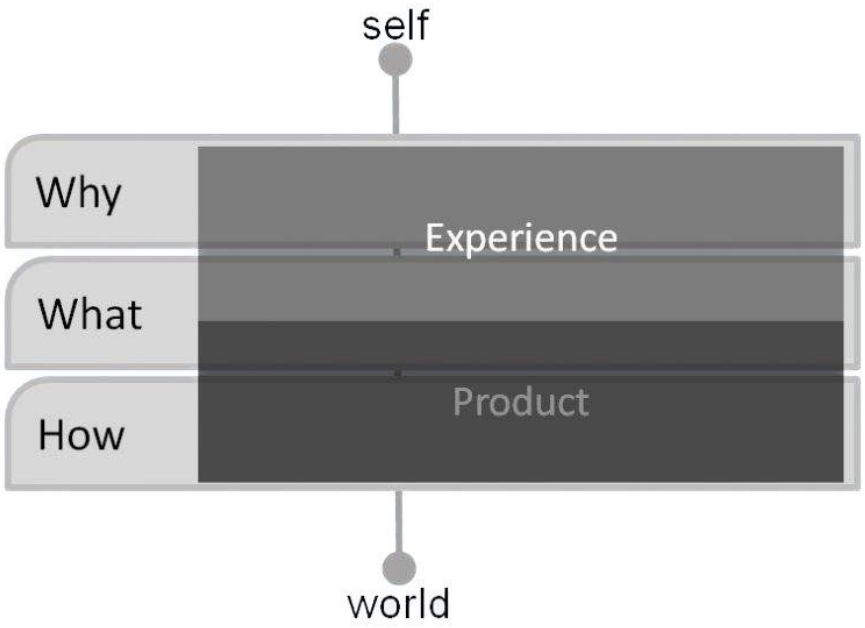


Figure 5.4: Three levels to consider when designing technology-mediated experiences. [50]

Nevertheless, experience changes over time, as van Boven (2005, p. 137) puts it: "As one forgets the incidental annoyances and distractions that detract from the online, momentary enjoyment of an experience, one's memory of an experience can be sharpened, levelled, and 'spun' so that the experience seems better in retrospect than it actually was."

One study [50] conducted a heuristic evaluation of popular fitness applications, identifying several areas lacking in user interface and experience design:

- Utilize simple and meaningful icons.
- Employ high-contrast color combinations for fonts and graphics against the background to ensure readability and visibility; avoid using blue, green, and yellow in close proximity.

- Increase the size of user interface elements in general to enhance accessibility.
- Ensure that the navigation structure within the UI remains concise, straightforward, and easy to follow.
- Provide support for user control and freedom in navigating the application.

5.3 UI for Interactive Walls

We discussed interactive walls in the first chapter of this thesis. This section will delve into the challenges of creating user interfaces and experiences on large interactive walls, highlighting key considerations for designers of applications tailored to such mediums. While some information may overlap with what was previously discussed, this section will focus specifically on the unique hurdles associated with designing interfaces for this particular platform.

The interactive wall, accessible to anyone without special tools or skills, offers a unique interaction paradigm distinct from traditional desktop computers. While it can reward sustained attention like computers, it also supports a more casual interaction pattern by forgoing delicate controls and the inert sitting posture. Certain applications benefit from the large size presentation offered by interactive walls, particularly for showcasing objects at lifelike proportions. For example, a home furnishings retailer might gain a competitive edge by providing customers with a life-size virtual mockup of various décor options.

It's worth noting that unlike most other screens, users touching an interactive wall may be unable to see the entire surface simultaneously, except at a steep viewing angle. This characteristic informs design choices; for instance, an application such as a puzzle may involve localized tasks for primary users while engaging onlookers with the broader context.

Successful interactive wall applications must [51] meet three criteria: attracting and engaging interacting users, ensuring user satisfaction with performing interactions in front of an audience, and providing entertainment, sales, or educational value to onlookers. In this regard, interactive wall applications share more similarities with blackboards than personal computers.

Arcade games offer a successful example of public computing, with dynamic content that can be easily updated to cater to different audiences and contexts. Unlike passive digital signage, touch screens enable interaction and feedback from users, allowing for greater flexibility in content delivery.

Traditionally, arcade games utilize an "attraction loop" to engage users and provide guidance on gameplay. However, optimizations for traditional screens may not translate well to interactive walls, requiring designers to rethink their approach. High resolution is essential for interactive walls to ensure quality and detail at close range, enhancing the user experience during interaction. Therefore, designers should prioritize delivering a rich visual experience during wall use, rather than afterwards.

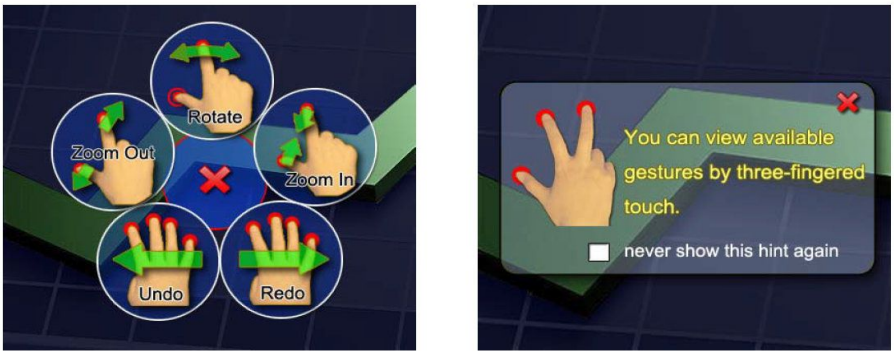
Designing for interactive walls raises questions about user interaction, initial expectations, and suitable deployment locations. Simple touch inputs such

as touching, releasing, and dragging objects with a finger or fingers are fundamental, but designers must also consider how users will perceive and interact with the wall's capabilities, including multi-touch functionality.

Using a single hand rather than two hands offers advantages such as reducing occlusion caused by the hands, making it easier to see targets on the wall display, especially during multi-user interactions. Initially, users tend to prefer simple gestures familiar to them from using systems with mouse inputs. However, this presents a contradiction regarding the ideal recommendation—whether to use one hand or two.

Direct gestures, by their nature, are easier for users to discover and adopt. For multi-touch wall applications, allowing users to gesture with minimal effort is crucial, considering that wall users are more prone to fatigue than tabletop users. Additionally, the limited number of accurately recognizable gestures by software necessitates clear cues and guidance in the user interface.

To aid users, the UI should make it clear that the wall is touch-enabled and capable of handling multiple touches and gestural interactions. A good UI should assist users in identifying applicable gestures for relevant tasks and consistently cue the most efficient gesture to prevent needless repetition.



(a) Hint instrument for cuing applicable gestures

(b) Tip bar hovering on active object

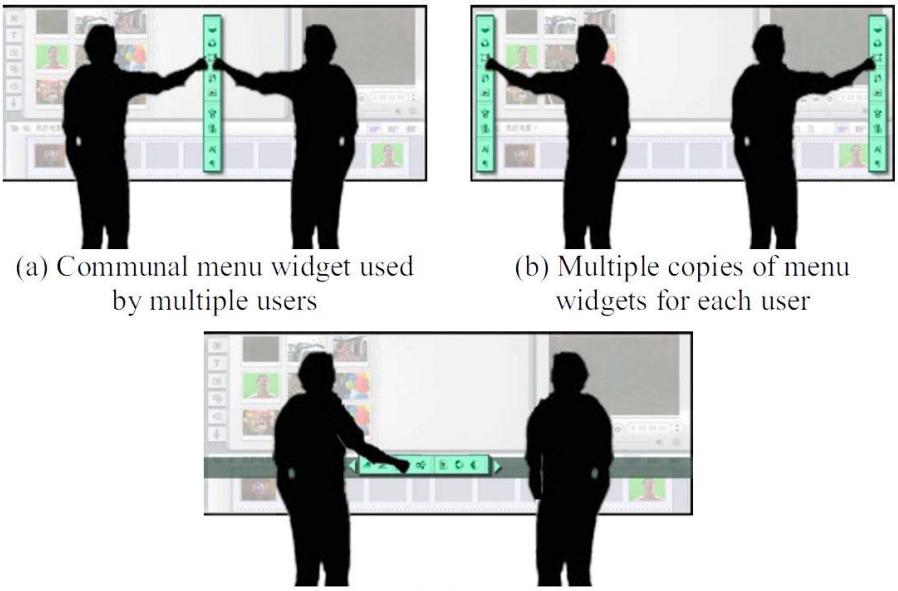
Figure 5.5: Providing contextual cue for interaction. [52]

When it comes to multi-user settings, a single shared space on the wall may be preferable for many tasks, although conflicts may arise when multiple users interact with the same elements simultaneously. Providing separate toolbars for each user or implementing a sliding menu track can address such issues.

The use of menus on multi-touch interactive walls[12] presents an interesting UI challenge. While many gestural interaction systems aim to avoid menus, users may instinctively look for them in disorienting situations. Implementing a "Close" menu item or allowing menus to slowly disappear can enhance user experience.

Recognizing the importance of gesture recognition and error prevention, the MTIW UI should provide convenient ways to undo operations and confirm unrecoverable processes. Collaboration on MTIW is significantly faster

[12] MTIW



(a) Communal menu widget used by multiple users

(b) Multiple copies of menu widgets for each user

(c) Sharing a "sliding" menu widget

Figure 5.6: Menu access amongst multiple users. [52]

than on tabletops, emphasizing the need for straightforward interfaces that accommodate diverse user roles and perspectives.

In conclusion, an effective MTIW UI should facilitate fluent interaction [52], interweaving social and computer communications, while accommodating users with different roles and providing clear visibility of actions for enhanced group awareness.

Text input and editing play a fundamental role in interacting with computers and electronic devices. Despite the ubiquity of keyboard designs based on mechanical typewriters, such as the QWERTY layout, alternative forms of text input aim to create more accessible typing experiences, especially on interactive walls.

Handwriting recognition and speech recognition are technically possible on interactive surfaces but suffer from speed limitations and correctness issues. Multi-user interactive surfaces present challenges related to privacy and ambiguity regarding the currently speaking person.

One major drawback of using a keyboard on a touch interface is the lack of tactile feedback. Additionally, on-screen full QWERTY keyboards may cause occlusion of the lower part of the keyboard and ghost inputs with the palms.

User familiarity with the input technique is crucial for acceptance. Therefore, an input layout resembling the 12-key keypad commonly found on mobile phones is preferred over a full QWERTY layout. Adaptive layout schemes can further enhance the input interface by positioning buttons according to the user's hands and fingers.

Research [53] on this topic proposed a prototype keyboard, where each key on the keyboard represents multiple characters, but since on-screen keyboards may suffer from viewability issues when arms and hands block the screen.

That's why they implement visual character aids positioned above the keys help users avoid peck-and-hunt behaviour. Typing words involves pressing buttons containing the correct keys in sequence. Word prediction algorithms interpret key combinations and suggest words containing those keys. Typing speed is improved by locking keys to specific characters while typing, enhancing efficiency and accuracy.

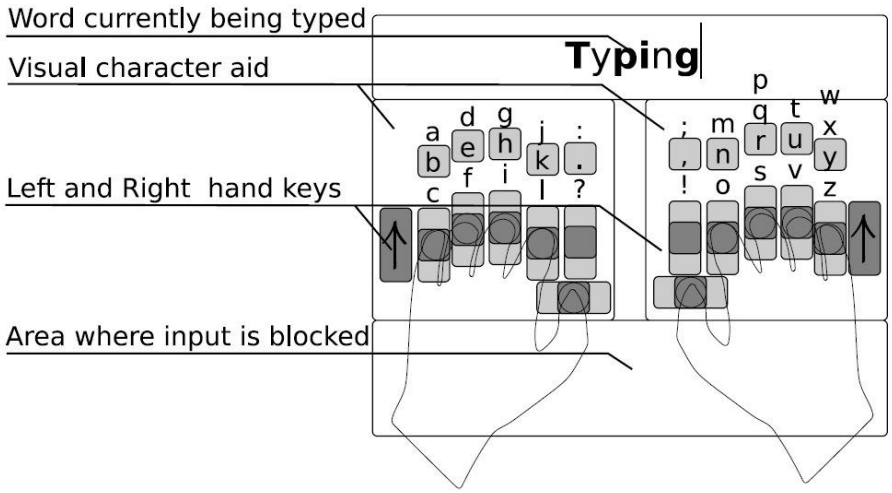


Figure 5.7: Block layout of the keyboard. [53]

Unfortunately, utilizing traditional on-screen keyboards or keyboard proposed before for text input on the INITI interactive wall poses challenges, as the entire keyboard area would be occluded by the user's body. In this case, the most suitable solution would be to employ an external keyboard or implement simpler input methods such as sliders for entering numbers or letters.

5.4 Dark patterns

Dark patterns, akin to UI, UX and games, are defined diversely depending on the context and domain of their application. Here are a few of those definitions:

> *"A dark game design pattern is a pattern used intentionally by a game creator to cause negative experiences for players which are against their best interests and likely to happen without their consent."* – J. Luguri [54]

> *"Dark patterns refer to user interfaces deliberately crafted by designers to confuse users, hinder their ability to express genuine preferences, or manipulate them into specific actions."* – J. Zagal [55]

> *"Tricks used in websites and apps that make you do things that you didn't mean to, like buying or signing up for something."* – H. Brignull [56]

Studies have identified four facets of dark pattern definitions:

1. Characteristics of the user interface that can affect users.
2. Mechanisms of effect for influencing users.
3. Role of the user interface designer.
4. Benefits and gains resulting from a user interface design.

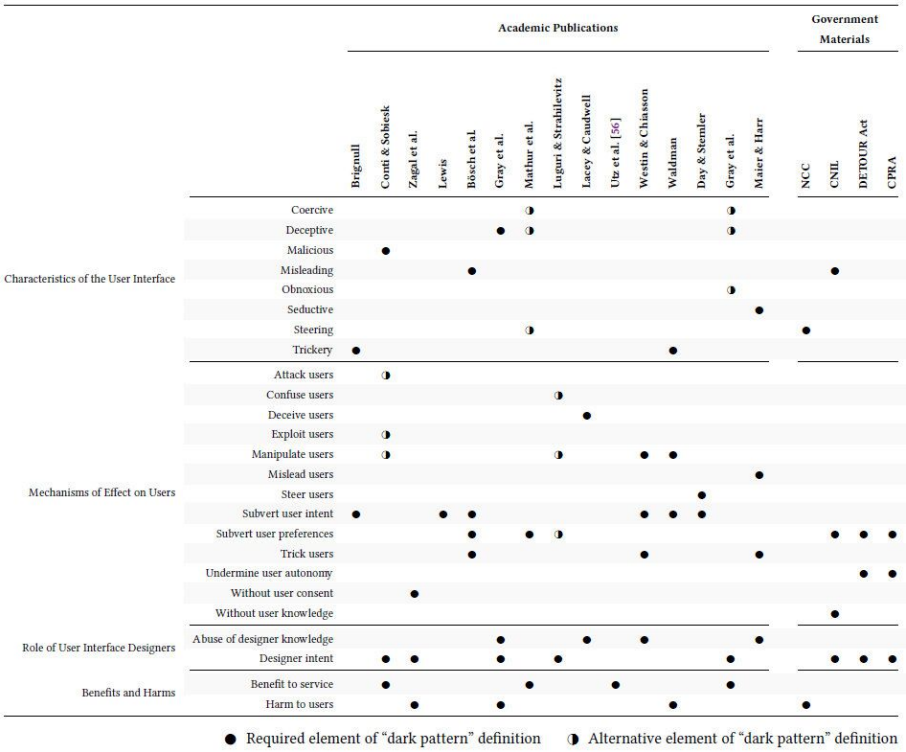


Figure 5.8: A classification of various dark patterns definitions in academic literature, law and policy. [56]

Definitions involving characteristics of user interfaces may vary in their terminology and implications. For example, one definition may describe dark patterns as "tricks," while another emphasises that dark patterns are "malicious." Additionally, even when definitions share common elements, those elements may be necessary for one definition but not for another. Another challenge in defining dark patterns is the lack of specificity in recurring terminology.

Brignull's original definition comprised 12 types of dark patterns, yet various researchers and fields have identified different types based on their specific contexts and needs. For a more comprehensive and exhaustive list, refer to the paper by Mathur et al. [56]. Since there are multiple definitions and classifications, this thesis will not enumerate all of them but will provide classifications from two other papers.

Table 5.2: Types of Dark Patterns. [57]

Type of Dark Pattern	**Description**
Bait and Switch	You set out to do one thing, but a different, undesirable thing happens instead. Adverts that are disguised as other kinds of content or navigation, in order to get you to click on them.
Disguised Ad	When adverts that are disguised as other kinds of content or navigation, in order to get you to click on them.
Forced Continuity	When your free trial with a service comes to an end and your credit card silently starts getting charged without any warning. In some cases this is made even worse by making it difficult to cancel the membership.
Friend Spam	When a site asks for your email or social media permissions under the pretence it will be used for a desirable outcome (e.g. finding friends), but then spams all your contacts in a message that claims to be from you.
Hidden Costs	You get to the last step of the checkout process, only to discover some unexpected charges have appeared, e.g. delivery charges, tax, etc.
Misdirection	The design causes your attention on one thing in order to distract your attention from another.
Price Comparison Prevention	The retailer makes it hard for you to compare the price of an item with another item, so you cannot make an informed decision.
Privacy Zuckering	You are tricked into publicly sharing more information about yourself than you really intended to. Named after Facebook CEO Mark Zuckerberg.
Roach Motel	It's very easy for you to get into a certain situation, but then makes it hard for you to get out of it (e.g. a subscription).
Sneak into Basket	The site makes it easy for you to add an item to your shopping basket, but somewhere in the purchasing journey the site sneaks an additional item into your basket, often through the use of an opt-out radio button or checkbox on a prior page.
Trick Questions	You respond to a question, which, when glanced upon quickly appears to ask one thing, but if read properly asks another thing entirely.

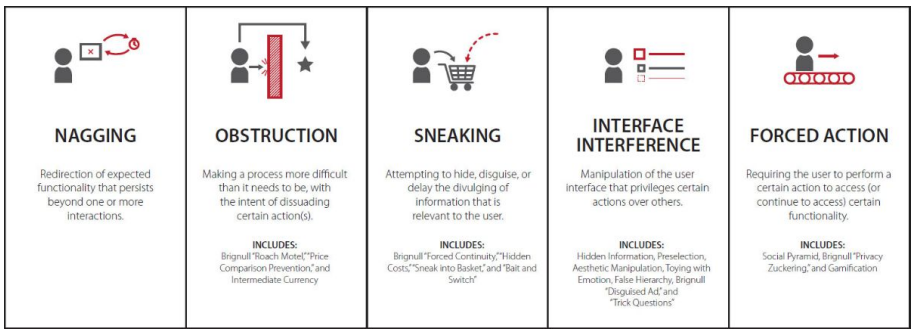


Figure 5.9: Summary of dark pattern strategies derived from analysis of corpus made by [57].

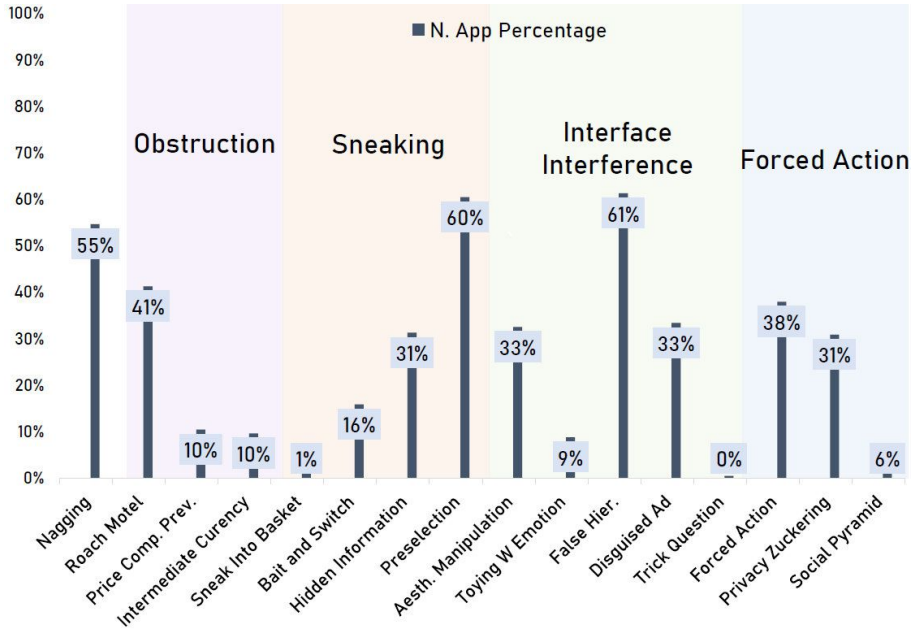


Figure 5.10: Percentage of apps containing each subcategory. [58].

It's crucial to differentiate between dark patterns and anti-patterns. Anti-patterns represent suboptimal solutions to specific problems and are generally advised against [55]. However, while using an anti-pattern may not be ideal, it would be inaccurate to label it as unethical. Poor design choices often stem from factors such as ignorance, trade-offs, or constraints on time and resources. Employing anti-patterns may result from such circumstances and can lead to less-than-ideal outcomes. While they may not be the best approach, they do not necessarily imply unethical behavior.

The usage of dark patterns appears to be widespread across various digital platforms, with significant prevalence observed in popular shopping sites and free Android apps. Studies [54] suggest that more than 11 percent of popular shopping sites employ dark patterns, and there is a correlation between the

popularity of the site and the likelihood of employing multiple dark patterns. Additionally, an astonishing 95 percent of free Android apps have been found to utilize dark patterns in their design and user experience.

While the effectiveness of dark patterns has not been extensively studied in research papers, their widespread adoption across different platforms suggests that they are likely to be effective in influencing user behavior. However, it's important to note that much of the research on dark patterns may be conducted in-house by companies and not publicly disclosed, making it challenging to fully understand their impact on users. Nevertheless, their prevalence indicates that they are perceived as effective tools for achieving certain goals, whether those are increasing sales, user engagement, or other objectives.

A study by Di et al. [58] tested the effectiveness of dark patterns in a real-life scenario and found significant results. In the mild version of the Dark Pattern, users were given the option to either 'Accept (recommended)' the program or click on 'Other options,' where they could eventually refuse the plan. In the aggressive version of the pattern, upon decline, users were asked to read additional information about identity theft and then wait ten seconds. The authors found that 26% (mild option) and 42% (aggressive option) of the treated participants accepted the plan, in contrast to only 11% among the participants without Dark Patterns.

Among the 240 studied apps, 95% included one or more Dark Patterns in their interfaces. Overall, 1,787 Dark Patterns were found among all apps, with an average of 7.4 malicious designs per application (standard deviation: 5). Almost 10% of the apps included zero, one, or two Dark Patterns ($N = 33$), 37% of the apps contained between three to six Dark Patterns ($N = 89$), while the remaining 49% included seven or more ($N = 118$).

Regarding DP Classes in Mobile Apps, among the five DP macro-categories, apps contained an average of 2.7 classes each (standard deviation: 1.1), with 37% of the apps including three ($N = 89$), 25% with four or five ($N = 62$), 23% having two ($N = 55$), and 14% including one or none ($N = 34$).

Considering the 16 subcategories, apps contained 4.3 classes on average (standard deviation: 2.6). Most apps (63%, $N = 152$) contained at least four different subcategories. The most frequent DP subcategory was Nagging ($N = 352$), followed by False Hierarchy ($N = 299$) and Preselection ($N = 210$).

In the user survey, the majority of users did not spot malicious designs in the app containing Dark Patterns (55%), some were unsure (20%), and the remaining found a malicious design in the app (25%). In the control task, 86% of users were able to recognize that the app had no Dark Patterns. Overall, out of 366 participants that answered the open question, only 7% somehow mentioned a Dark Pattern in their answers.

And as one participant in the study said, dark patterns might be so common already, that we just do not consider it any more.

5.4.1 Regulations

Generally, regulations defining interface standards do not require extensive specificity. Consequently, regulators often take a case-by-case approach rather than applying a single standard to address distinct issues. From a regulatory objectives perspective, the focus is more instrumental than normative. Normative arguments for implementing regulatory objectives typically stem from the

objectives themselves rather than abstract compliance with regulations. This perspective does not inherently advocate for why we should care about financial losses, privacy harms, or cognitive burdens beyond compliance with the law. However, it offers the advantage of facilitating the formulation of regulations into measurable metrics for empirical research, which is typically more feasible than adapting normative principles to research. For more on the topic of regulations refer to this [56] paper.

5.4.2 Games

This section will explore the presence of dark patterns in games, drawing a connection to the previous discussion on child play. While the application under consideration is built using the Unity game engine, the focus extends beyond the specifics of the engine to examine dark patterns within the broader context of gaming.

Playing games is inherently a social activity. The subsequent dark patterns serve as illustrations where players' social capital, broadly defined [55] as the value attributed to their social standing and relationships, is jeopardized. To determine if a dark pattern exists, one may consider the following questions:

- Could the player's social standing (friends, respect, etc.) be diminished as a result of playing the game?
- How likely is the player to feel that she must play primarily because of a sense of social obligation?

Dark patterns in games encompass various categories: [55]

- **Grinding**: This temporal dark pattern coerces players into spending excessive time in the game solely to prolong its duration.
- **Playing by Appointment**: Another temporal dark pattern, this requires players to adhere to specific times or dates dictated by the game rather than their own preferences.
- **Pay to Skip**: This monetary dark pattern forces players to pay in order to continue playing or to bypass the grind.
- **Pre-Delivered Content**: A monetary dark pattern where certain game content or features are included in the initial purchase but remain inaccessible until players pay an additional fee.
- **Monetized Rivalries**: Exploiting player competitiveness, this monetary dark pattern encourages spending money to achieve in-game status, such as high leaderboard rankings, commonly known as "Pay to Win."
- **Social Pyramid Schemes**: This social capital-based dark pattern traps players into feeling socially obliged to play and recruit others, creating a pyramid-like structure of social pressure.
- **Impersonation**: In this social capital-based dark pattern, player actions may be broadcasted without their awareness, leading to potential negative consequences on their real-life social relationships, particularly among those uninterested in the game.

And then there are shades of gray, which are not exactly dark patterns.

Encouraging Anti-Social Behavior: Many games require that players engage in social activities considered unethical outside of a game's context.

Psychological Tricks: There is an increasing interest in applying insights and results from psychology and behavioral economics to games. How do we draw the line between using this knowledge to provide more interesting, engaging, and satisfying gameplay experiences (good) and exploiting players' cognitive biases and predictably irrational behavior to make more money (negative)?

Games for Other Purposes: Games are often developed for purposes beyond entertainment. Abt's "serious games", games whose primary purpose was educational rather than entertainment, are but one example. Surely, this is a good thing? However, consider von Ahn's notion of games with a purpose: "What if people playing computer games could, without consciously doing so, simultaneously solve large-scale problems?" Are the players of von Ahn's games being manipulated and taken advantage of? To be fair, von Ahn's site does inform players that by playing they help train computers to solve problems that could broadly benefit society.

Heart of Darkness? Perhaps the patterns studies have identified, although aligned with the definition of dark pattern, do not seem all that vexing. As studies have noted, there is a certain degree of subjectivity involved that makes dark patterns particularly difficult to characterize. What one person may find acceptable, another might find galling. In keeping with previous work in game design patterns, there is no one-design-affects-all-pattern that is guaranteed to have the same effect on all players. An individual player's context is also significant. When we argue that dark patterns often manipulate or take advantage of a player, we are also making assumptions on a player's gullibility (or willingness to be manipulated). While a game may employ dark patterns, these may be transparent to players, thus rendering them ordinary patterns or ineffective. By transparency, we mean that players develop literacy in manipulation. One cannot give reasonable consent to manipulation if one does not have the literacy with which to understand when persuasion is occurring and how it is being conveyed or effected [55], especially given that even when we are aware of our own biases, we still find it difficult to act against them.

Chapter 6

Implementation and Testing

This chapter delves into the Unity game engine, its integration with the INITI interactive wall, and offers tips for application development. Subsequently, it presents the implementation of the fitness application itself, followed by user testing.

6.1 Unity

Unity is a real-time development platform created by Unity Technologies, initially unveiled and launched in June 2005 at the Apple Conference as a Mac OS game engine [59]. Over time, it evolved into a cross-platform tool used for developing three-dimensional and two-dimensional games, interactive simulations, scenes, and applications across various industries. Apart from gaming, Unity finds applications in fields such as automotive, architecture, film, and more.

After launching Unity for the first time, users encounter a scene setup tailored to their project, whether it's 2D or 3D, along with options to select rendering pipelines and other settings that can be adjusted later, albeit with some complexities. Once project settings are configured and the engine initializes, users are presented with an empty scene view, a hierarchy panel, an asset browser, and an inspector. Additional windows are accessible through tabs or can be revealed later.

The hierarchy panel adopts a tree-like structure, with parent and child nodes behaving intuitively. The asset browser serves as a repository for assets contributed by programmers, designers, artists, and other collaborators. These assets are utilized to construct the game within the scene view.

The inspector provides a detailed view of all components attached to assets, highlighting Unity's component-based architecture. The essential transform component is always present, while other commonly used components include sprite renderers, colliders, and scripts. Unity's component-based approach facilitates ease of editing and customization, with numerous additional components available to cater to diverse development needs.

In Unity, a typical workflow for game creation involves creating a scene and populating it with assets, many of which are converted into prefabs. Prefabs are pre-configured GameObjects, representing objects in the game world, that store a complete set of components, properties, and settings. They serve as

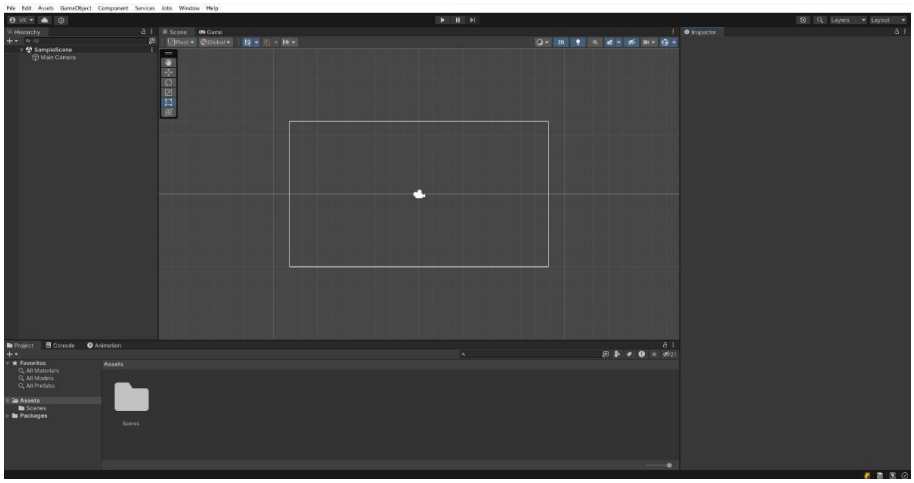


Figure 6.1: Default empty unity screen.

reusable assets that can be instantiated multiple times in different game scenes, akin to classes and templates in object-oriented programming languages.

Prefabs often contain scripts that execute the logic of the game. These scripts are written in C#, Unity's primary programming language. In C#, every script class is inherently a child of the MonoBehaviour class, which provides access to various Unity methods and the game loop, including Start and Update methods. This inheritance structure allows developers to leverage Unity's built-in functionality and seamlessly integrate custom logic into their games.

These are the fundamental components of the Unity engine, along with a brief introduction. For further information and tutorials, I recommend exploring the Unity website and documentation, as well as downloading and examining example games and scenes provided by Unity. Additionally, watching YouTube series from creators like Brackeys, Jason Weimann, and Game Maker's Toolkit, among others, can be helpful. Joining communities where you can seek assistance is also valuable. However, the most crucial step is to begin learning by doing, gradually expanding your skills as necessary.

6.2 Integration of INITI Wall in Unity

To integrate INITI Wall functionality, follow these steps:

1. Find an example Unity project for the INITI wall or any other Unity project that utilizes INITI functionality.
2. Then find the INITI folder in the asset browser, right-click on it, and select *Export Package....*
3. Create or open your own project and select *Import Package/Custom Package...* or drag and drop the exported file.
4. In the script file, don't forget to include *using initi.prefabScripts;* at the top. Change the inheritance from MonoBehaviour to BaseHittable, which allows you to use the *Hit()* method to detect touch on the wall.

5. Add the script that contains touch/hit logic to an asset/prefab and make sure the prefab has a collider attached; without it, touch detection won't work.

6. Finally, add the *Input* prefab from *Assets/Initi/Prefabs* to every scene where you want to detect touch.

With those steps complete, the touch should be correctly mapped to unity input, but there are several tips to make integration, development and testing more enjoyable.

- Download the TUIO simulator from this GitHub repository [60]. This allows you to test touch inputs from the wall at home by simulating touch inputs. After downloading, turn on the simulator and configure the *Server port to 33333* and *Local Port to 12345*; the rest can be left unchanged. Next, open Unity and enable *Edit/Project Settings/Player/Resolution and Presentation/Run in Background*. This ensures that the game won't freeze while using the simulator. Then, find the *Input* prefab, press the plus button in the input lists, and add *TuioInput*. With all these steps completed, turn on the simulator and your game, and the inputs should get mapped accordingly.

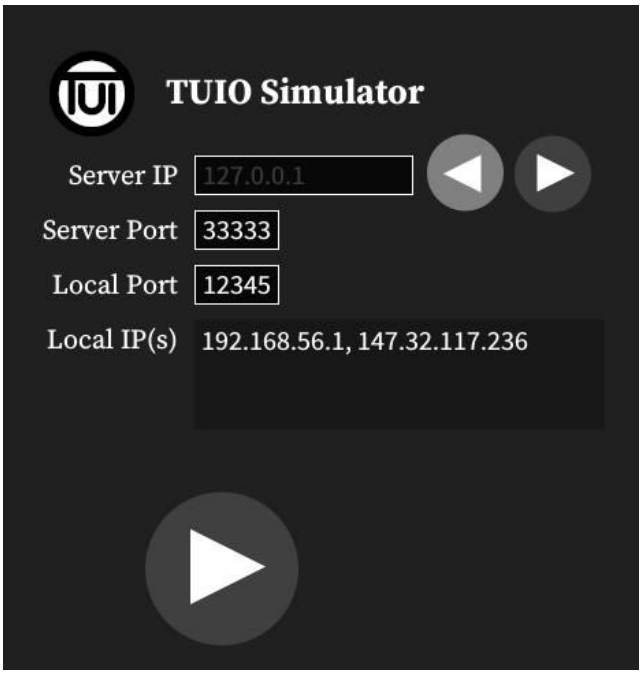


Figure 6.2: TUIO configuration.

- Only objects with colliders are able to be interacted with, meaning built-in Unity UI elements won't be interactable with the wall touch. Instead, use game objects as buttons and assign them a *public UnityEvent onClick*, which allows you to call any method using Unity events. One challenge with this approach is that game objects will change positions and scale

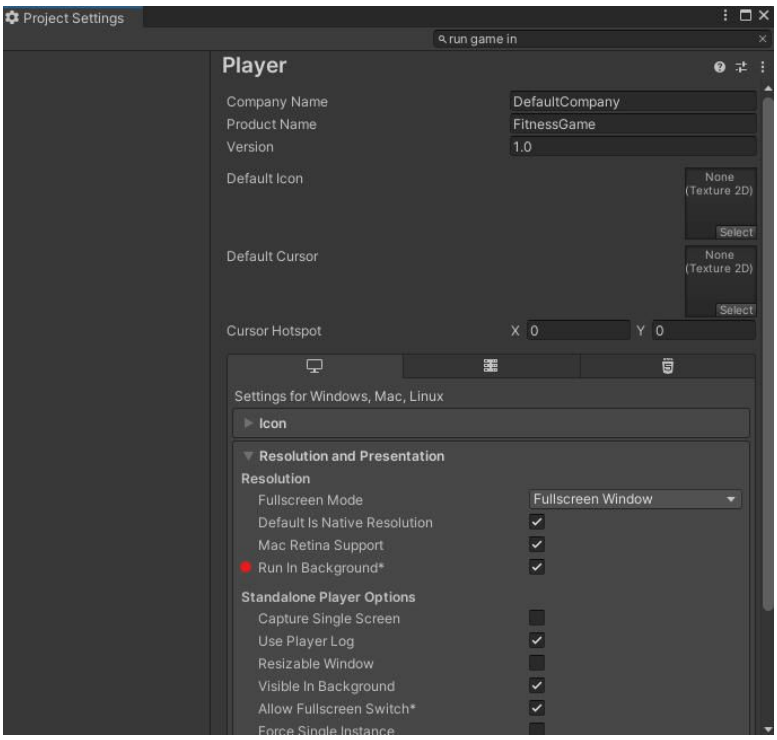


Figure 6.3: Run in background location.

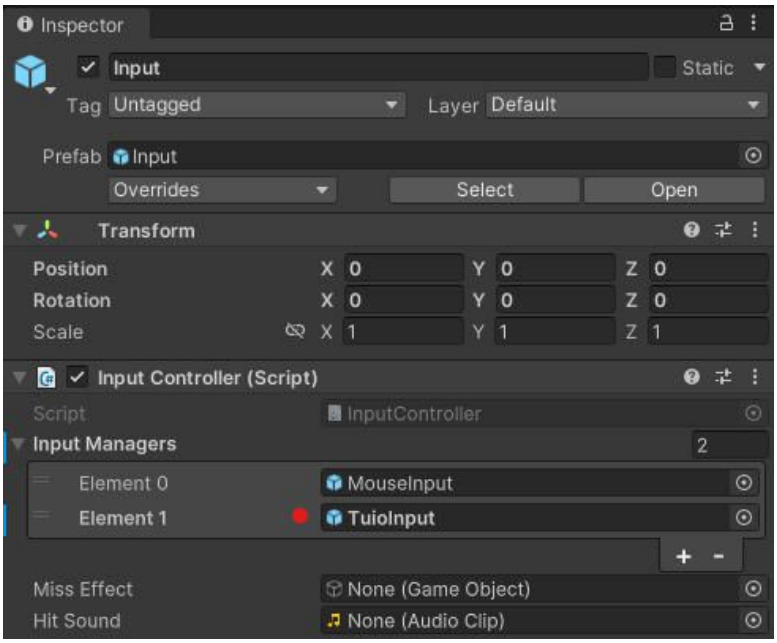


Figure 6.4: TUIO input.

with different resolutions and aspect ratios, which is inevitable. However, you can mitigate the negative effects by using these scripts [61] that allow you to anchor game objects to the view. While it's not perfect, it gets the job done.

- Develop your game in a resolution of 3840x2160 (4K) with a stable aspect ratio of 16:9, as this matches the resolution of the data projector in the ggLab at school. Additionally, detach the game window from Unity and maximize it. This setup will provide an experience that closely resembles what you'll see on the wall. It is also important to keep in mind the low brightness and contrast of dataprojector when developing visuals, as they can be sometimes invisible on the wall.

- Encapsulate or wrap the *BaseHittable* class and its methods into your own file and class. You can detect interactions using this encapsulated class. Many games in development are using a script created by Matěj Chlan, which can be found here [62].

To deploy your game on the wall, follow these steps:

1. Build your game.

2. Create two thumbnails for the game:

   a) A small thumbnail that shows in the game selection screen with a resolution of 640x390. Save it as `buttonImage.png`.

   b) A larger preview of the game that is shown when the game is selected with a resolution of 3235x1770. Save it as `windowImage.png`.

3. Locate the INITI folder in the media server, either in `C:\initi` or on the desktop as a shortcut.

4. Place the thumbnails into the folder where your game is built and place the entire build into the INITI folder.

5. Open the file `ui\games.json` and add the name of your game/folder to the existing list.

6. Restart INITI playground and start playing!

6.3 Design Considerations and Development

The objective is to develop a fitness application leveraging insights from previous chapters on the INITI interactive wall, active digital play, physical health, gamification, and user experience.

Functional requirements: These outline what the application must do and what it should avoid. The application must support touch input from the wall and offer various exercises accessible within the user's reach. It should include diverse exercise types with clear instructions and optional leaderboards to encourage a competitive spirit.

Non-functional requirements: These specify operational capabilities and constraints. The application must be built in Unity using C# and be compatible with the INITI wall in ggLab. Desirable features should align with the Kano model, offering attractiveness and personalization through multiple levels, tasks, badges, and challenges.

Insights from the chapter on the wall inform the UI and game element design, ensuring they are tailored to fit the ggLab wall's size and visual requirements. Visuals should be simple, attractive, and high contrast for easy identification, with readable text that avoids user obstruction.

From the play chapter, it's clear that the application should provide an immersive and enjoyable experience, motivating users to engage willingly. While outdoor environments may not be feasible, the app should offer multiple interaction methods, such as touch, throwing, and mimicking exercises.

Considering physical health, the app should encourage exercise to improve overall well-being. This will involve a combination of exercises targeting different body parts and reaction times, gamified elements like score systems and countdowns, and an engaging virtual environment to make exercising enjoyable.

6.4 Implementation

This section provides an exploration of the application's implementation, covering file organization, data structures, design patterns, exercise creation, UI composition, and scene management.

File organization follows best practices, with assets structured into folders such as Scripts, Scenes, and Prefabs. Within the Scripts folder, further categorization includes exercise-specific, touch detection, UI, and navigation scripts. Each scene represents a distinct exercise, with exceptions like the main menu and boundary setting scenes, which focus on UI elements and instantiate prefabs set to `DontDestroyOnLoad()`.

Prefabs play a pivotal role, particularly for targets. The main target comprises two game objects: the root, housing transform and hit detection components, and the child, featuring a sprite renderer and color change script. Variant prefabs for each exercise utilize different sprites, allowing for global changes while preserving individuality. Unity's Layers and Tags streamline collision detection and target identification for scoring. Additionally, button prefabs are designed as game objects for easy editing and component addition across scenes.

Scripts are organized into manager, touch detection, and exercise categories. Manager scripts, such as `UIManager`, `ScoreManager`, `GameBoundary`, and `PrefabLibrary`, adhere to the singleton design pattern for unique instantiation and accessibility across scenes. Notably, `GameBoundary` defines the playable space and manages input across scenes to enable touch functionality.

Touch detection scripts leverage a class provided by Matěj Chlan, inheriting from INITI's `BaseHittable` class. This inheritance allows for the creation of classes like targets and buttons, utilizing `OnPress()` methods. Modifications to `BaseInteractive` include spawning a visual aid indicating touch registration. `OnPress()` methods handle target logic, including score counting and object destruction, while buttons call `UnityEvent` for flexible method invocation.

```
public class HitDetection : BaseInteractive {
    [SerializeField] private LayerMask layerMask;

    public override void OnPress(Vector2 hitPosition) {
        if (ScoreManager.instance != null) {
            if (this.tag == "F1Experience") {
                ScoreManager.instance.IncreaseF1Score();
            } else if (this.tag == "ShortExperience") {
                ScoreManager.instance.IncreaseExperienceScore();
            }
        }

        Destroy(this.gameObject);
    }
}
```

Listing 6.1: Sample code for identifying collisions with targets.

```
public class ButtonPressDetection : BaseInteractive {
    [Header("Button Press Events")]
    public UnityEvent onClick;

    public override void OnPress(Vector2 hitPosition) {
        onClick.Invoke();
    }
}
```

Listing 6.2: Sample code for button press.

Exercise scripts are structured around object-oriented programming principles, mirroring the approach taken with target prefabs. A `ExerciseBase` script encapsulates core functionality such as exercise initialization, progress tracking, and prefab spawning. Each exercise type extends this base script and overrides the `StartExercise()` method, providing specific parameters like *name*, *duration*, and *description*. Individual exercises determine where objects are spawned based on their unique logic.

The `ExerciseManager` orchestrates these exercises, acting as a central hub without the singleton pattern. It maintains references to each exercise, initializes and starts the appropriate exercise based on the selected scene, and manages a list and queue of exercises. Now is an opportune moment to delve into the distinction between experiences and exercises. There are three types of experiences:

- **Freestyle Experience:** randomly selects an exercise from the list each time, ensuring that the same exercise does not repeat consecutively. Exercises involving reaction speed are excluded from this selection.

- **P.H.A.T. Experience:** Peripheral Heart Action Training, combines upper and lower body exercises alternately, aiming to improve longevity. It includes exercises for legs, upper body, core, and balance, each lasting 30 seconds, totaling a short 3.5-minute workout.

- **Reaction Speed Experience:** inspired by F1 reaction speed trainer machines, evaluates how many targets the user can hit within a limited timeframe.

And these experiences are built using six distinct exercises, each inheriting from `ExerciseBase` and differing in their initialization and target spawning logic, as explained below:

- **Leg Movement:** Targets spawn alternately on the left and right sides, encouraging movement of the lower body. This exercise requires additional space in front of the wall, with a "base" set up two meters away for the user to return to after each touch.
- **Arms Movement:** Targets spawn within arm's reach to engage the upper body.
- **Throwing:** Designed to train grip, upper body strength, and coordination. Users are required to stand on the "base" when throwing balls, targets spawn only on the top side of the game boundary.
- **Core:** Targets spawn on the top and bottom edges of the game boundary, engaging both core and leg muscles.
- **Leg Raises**: This is a mimicking exercise where users are instructed to follow instructions from the UI to improve overall stability. The goal of this exercise is to horizontally lift legs to perform leg raises as instructed.
- **Reaction Speed:** Targets spawn randomly in predefined "sockets" arranged in the shape of an X, with a total of eight sockets.

```
1  public abstract class ExerciseBase : MonoBehaviour {
2      public bool isActive = false;
3      public GameObject currentPrefabInstance = null;
4      public float countdown = 0;
5      public bool isCountdownActive = false;
6
7      public abstract void StartExercise();
8      public virtual void EndExercise() {
9          if (currentPrefabInstance != null) {
10             Destroy(currentPrefabInstance);
11         }
12
13         isActive = false;
14         UIManager.instance.ChangeCenterText("");
15         FindObjectOfType<ExerciseManager>().StartNextExercise();
16     }
17
18     public void StartCountdown(float exerciseDuration) {
19         isCountdownActive = true;
20         countdown = exerciseDuration + 1;
21     }
22
23     public void Countdown() {
24         countdown -= Time.deltaTime;
25         if (countdown < 0) {
26             countdown = 0;
27             EndExercise();
28         }
29         UIManager.instance.ChangeTimerText(Mathf.Floor(countdown).
       ToString());
30     }
31
```

```
32      public void SpawnPrefabs(GameObject prefabToSpawn, Vector3
        position) {
33          currentPrefabInstance = Instantiate(prefabToSpawn,
        position, Quaternion.identity);
34      }
35
36      public Vector3 GenerateRandomPositionInBounds() {
37          return new Vector3(RANDOM POSITION INSIDE GAME BOUNDARIES)
        ;
38      }
39
40      public void InitializeExercise(string exerciseName, float
        exerciseDuration, string exerciseDescription = "") {
41          UIManager.instance.ChangeTopText(exerciseName);
42          UIManager.instance.ChangeBottomText(exerciseDescription);
43          StartCountdown(exerciseDuration);
44          isActive = true;
45      }
46  }
```

Listing 6.3: Sample code of base exercise.

```
1   public class ExerciseLegMovement : ExerciseBase {
2       [SerializeField] private float exerciseDuration = 30f;
3       private readonly string exerciseName;
4       private readonly string exerciseDescription;
5
6       [SerializeField] private bool leftSide = true;
7       [SerializeField] private float middle;
8
9       private void Update() {
10          if (isActive) {
11              Countdown();
12              if (currentPrefabInstance == null) {
13                  SpawnPrefabs(PrefabLibrary.instance.
        prefabLegMovement, GenerateRandomPosition());
14              }
15          }
16      }
17
18      private Vector3 GenerateRandomPosition() {
19          if (leftSide) {
20              leftSide = !leftSide;
21              Vector3 left = new Vector3(RANDOM LEFT SIDE);
22              return left;
23          } else {
24              leftSide = !leftSide;
25              Vector3 right = new Vector3(RANDOM RIGHT SIDE);
26              return right;
27          }
28      }
29
30      public override void StartExercise() {
31          InitializeExercise(exerciseName, exerciseDuration,
        exerciseDescription);
32      }
33  }
```

Listing 6.4: Sample code for exercises, with specific details left out.

The remaining scripts are available on GitLab[13], as well as in attached files

[13] https://gitlab.fit.cvut.cz/kacervik/di-dip-interactive-wall-fitness-app

to this thesis. Here, only a basic understanding of how the application works is provided, with specific details omitted for simplicity and visual presentation. As for leaderboards, the application utilizes the Leaderboard Creator [63] extension module by Danial Jumagaliyev. This allows the leaderboards to be synced online using itch.io cloud servers, with itch.io serving as an interface for easy management. For specific implementation details, it is suggested to refer to the documentation or the *LeaderboardsManager.cs* file included in this thesis project.

As mentioned earlier, the visual design of this application is intentionally simple. The sans serif font *Bebas Neue* is predominantly used for most elements, except for the score, which utilizes the *Alarm Clock* font. The color palette is also kept minimal, consisting of three main colors: Eerie Black (#222222) and White (#FFFEFF) for text, and Black Olive (#363732) as the background color. While accent and highlight colors were considered, they were ultimately replaced by a changing color that transitions through the entire RGB spectrum for visual interest.

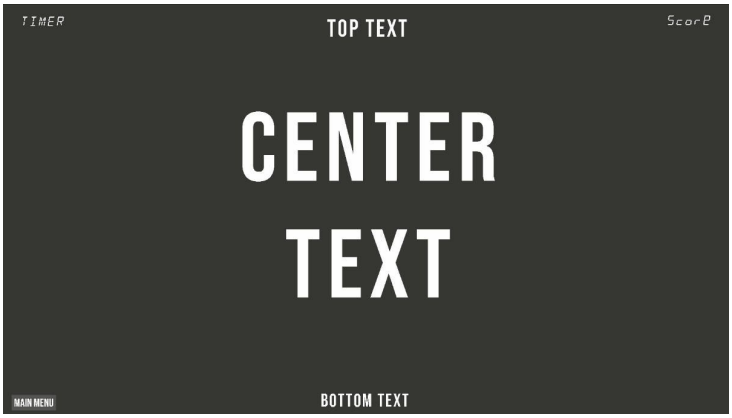


Figure 6.5: Initial design of main UI elements.

Regarding the exercise screen layout, it adheres to the same principle of simplicity. Targets are represented by simple geometric shapes such as squares, circles, or hexagons, each exercise having its own unique shape. The background design draws inspiration from retro wave neon styles and the backgrounds seen in video game "Just Dance."

All of these elements and experiences are managed into scenes, starting with *Boundary Setting* scene, which initializes UI elements, main camera, input management and other components that are needed throught the whole application. After that comes *Main Menu* scene, that is build from UI game objects and those allow us to switch to specific experience scenes such as *Freestyle*, *P.H.A.T.* or *Reaction Time*

6.5 User-Testing

The initial round of user testing, conducted in the ggLab with five participants, aimed to evaluate the functionality of the application. The majority of participants were students enrolled in the undergraduate programme at CTU

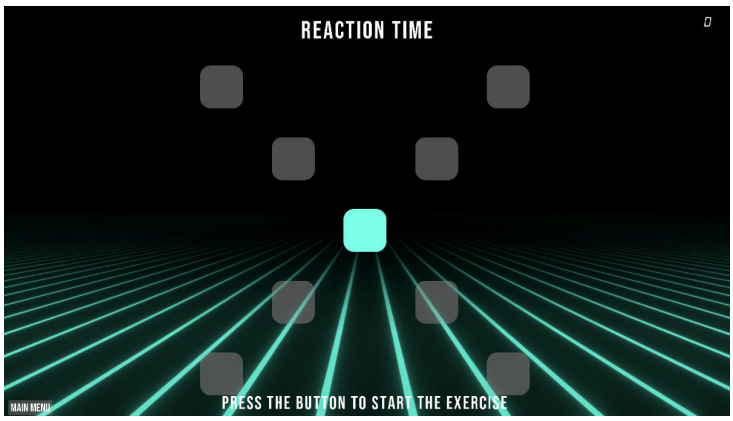


Figure 6.6: Visual representation of an exercise scene.

FIT, with all of them actively involved in developing games for interactive walls, except for one participant who was working on a classical computer game. Additionally, two faculty members participated in the testing process. Informal feedback from other students was also considered during the testing session.

The testing took place on the school premises in the ggLab located on the 14th floor. However, it's worth noting that the testing was conducted using an older version of the media server. An update to a newer version is planned a few days after the thesis deadline. Due to classroom settings, adequate space for leg movement was not available, which may have slightly impacted the testing results. Another challenge encountered during the testing was the improvised connection from the media server to the wall, resulting in hanging cables that obstructed and limited the testers' movements.

During the testing session, participants were instructed to explore the fitness application and provide feedback on the user interface, their overall experience, the clarity of the exercises, and their preferences. The results of the user testing are summarized below.

1. One participant encountered issues mainly with four aspects of the application: the absence of any audio feedback or music, unreadable bottom text due to obstruction, misunderstanding of the leg movement exercise, and the lack of a visual representation of the game boundary.

2. Another participant expressed a desire for targets to appear and disappear from the horizon of the scene, suggesting it would enhance the experience.

3. A participant struggled to understand the leg movement and leg raises exercises, mistaking it for a task involving touching targets with the feet. They recommended the inclusion of silhouettes to clarify exercise instructions. Additionally, they encountered navigation issues in the menus due to rapid touch input, and suggested improvements to the reaction speed exercise and the addition of experiences for multiple users.

4. Another participant echoed the suggestion for silhouette visuals and animations to enhance clarity and engagement in each exercise. Addition-

ally, they introduced Multiball, a company specializing in sport games for interactive walls, which could serve as valuable inspiration for further development.

5. One participant proposed that targets indicate the location of the next instantiation to maintain rhythm during exercises.

6. The developer identified several issues, including insufficient space in front of the wall, the need for refined target instantiation areas, challenges with UI scaling across different resolutions, visual clarity concerns, and leaderboard functionality issues due to a lack of internet connection.

Figure 6.7: Photo taken during user testing.

These adjustments based on user feedback demonstrate a proactive approach to improving the fitness application for the INITI playground interactive wall:

- **UI Scaling:** A temporary solution was implemented to address UI scaling issues by doubling the size of UI elements and adjusting other parameters for 4K resolution. However, a more permanent solution would involve linear scaling based on resolution.
- **Boundary Setting:** A rectangle representing the set area was added at the end of the boundary setting process for better visualization.
- **Reaction Speed Exercise:** A "Start" text was added to the middle target at the beginning of the exercise, which disappears when the exercise starts. This provides clarity on when the exercise begins.

- **Button Functionality:** All buttons were changed to trigger on hold with a slight delay to prevent multiple rapid or false touches.
- **Main Menu Enhancement:** A new section was added to the main menu with graphical representations and explanations of each exercise type to improve understanding.
- **UI Element Adjustments:** Various adjustments were made to UI elements for better visibility and readability, such as lowering top texts, relocating bottom text to the bottom left corner, and positioning the main menu button to the bottom right corner.
- **Exercise Spawn Adjustments:** The spawn locations of targets for each exercise were adjusted to enhance gameplay experience, ensuring targets are appropriately placed for optimal interaction:
  - **Leg Movement Exercise:** Targets now spawn further apart and closer to the sides of the screen, encouraging more movement from the user.
  - **Arms Movement Exercise:** Targets spawn on the rim of a circle, with the center located at the previous target, promoting fluid arm movements.
  - **Throwing Exercise:** Targets now spawn above the game boundary and below the top part of the screen, requiring players to throw balls instead of using their hands.
  - **Core Exercise:** Similar to the leg movement exercise, targets spawn closer to the edges of the top and bottom boundaries, engaging core muscles effectively.
- **Target Animation:** Targets now spawn with a short animation for improved clarity and identification, enhancing the user experience.
  - **Leg Movement Exercise:** Targets now approach from the horizon and move closer to the screen, enhancing the sense of depth and engagement.
  - **Other Exercises:** Targets for other exercises now appear on the spot with a slight "pop" animation, avoiding clutter caused by approaching from the horizon.
- **Silhouette Addition:** An animated silhouette of a person was added to the background of the leg raises exercise to guide users in performing the exercise correctly.
- **Color Adjustments:** Saturation and lightness of targets, background, and silhouette were adjusted to improve visibility on the dataprojector.
- **Audio Addition:** Three songs that play at random were added to the experiences along with the hit effect when target is destroyed.

All of the visuals are hand made using the combination Affinity Photo for 2D editing, DAZ Studio to acquire 3D model and Blender for posing and rendering.

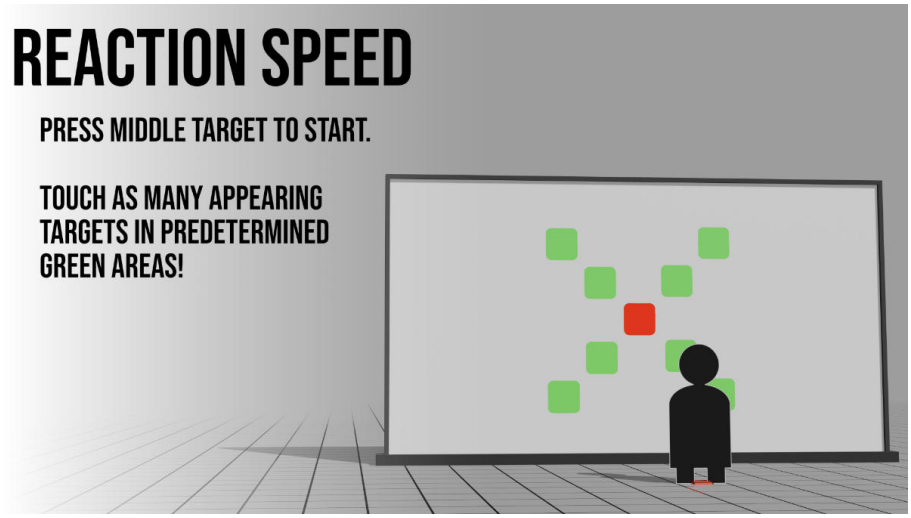


Figure 6.8: Visual representation of how to perform exercises.

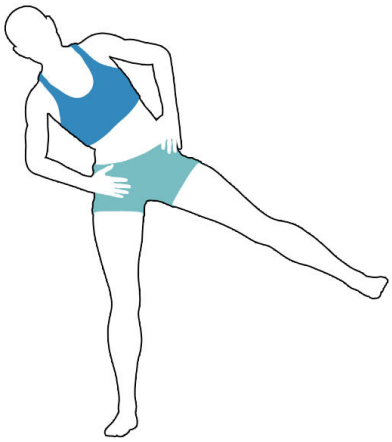


Figure 6.9: A single frame from the silhouette animation.

In the second informal round of testing, minor issues were identified with the application. These included low visibility of certain elements, animations not completing due to performance issues, and a malfunctioning start button in the reaction speed exercise. Fortunately, these issues were promptly addressed and fixed on the spot.

6.6 Future Improvements

The finished application is fully operational, yet there are certain areas that require refinement in future iterations. These include:

- **Visual Overhaul:** Implementing a cohesive visual style to enhance the overall appeal of the application.
- **Multi-User Mode:** Introducing functionality for multiple users to engage simultaneously, promoting collaborative or competitive experiences.
- **Multi-Target Exercise:** Designing exercises where multiple targets spawn concurrently, adding complexity and diversity to the gameplay. This would also allow to visualize the location of next target.
- **Custom Audio:** Incorporating tailored music and sound effects that complement the tempo and intensity of the exercises, enhancing immersion and making it more similar to rhythm games like *Beat Saber* or *Osu!*.
- **Enhanced Animations:** Developing more intricate animations for tutorials, exercise executions, and approaching targets, enriching the visual experience.
- **Idle Animations:** Implementing animations to play during periods of inactivity, maintaining user engagement and visual interest.
- **Target Zones:** Additional refinement of target spawning locations is necessary to prevent occlusion and ensure optimal visibility and accessibility for users.
- **Leaderboards:** Offline functionality for the leaderboards is required.
- **Personalization and Gamification:** Incorporating user profiles featuring custom settings, badges, challenges, and achievements to enrich the user experience and foster motivation.

Addressing these areas will contribute to the ongoing improvement and evolution of the fitness application, ensuring a more immersive and enjoyable experience for users.

"No project is ever finished, it just get's released." –Wren Weichman

Conclusion

The primary objective of this thesis was to develop a fitness application specifically designed for the INITI playground interactive wall.

Firstly, extensive research was conducted on various topics related to interactive walls, encompassing the technology behind these walls, child play dynamics, physical health implications, gamification principles, and user interface/experience design. This research was instrumental in identifying the limitations of interactive walls and informing the development of the fitness application.

The exploration of child play provided valuable insights into the elements that contribute to enjoyable play experiences and the factors that can detract from them. Additionally, the chapter on physical fitness underscored the importance of regular exercise for longevity and overall health, highlighting the significance of strength, balance, and cardiovascular fitness.

The investigation into gamification shed light on the concept itself and identified key elements essential for effective implementation. It emphasized the importance of intrinsic motivation in gamified experiences and cautioned against reducing gamification to mere pointification.

The section on user interface and experience delved into best practices for designing interfaces tailored to interactive walls, emphasizing visibility, accessibility, and the challenges posed by occlusion. This provided valuable guidance for creating an engaging and intuitive user experience.

In the second part of the thesis, implementation details of the fitness application were elucidated. This included defining the goals of the application, providing an overview of the Unity game engine, and explaining the process of integrating Unity with the INITI wall. Practical tips for application development were also shared, along with specific implementation details, script examples, and user interface design considerations.

Furthermore, user testing was conducted to gather feedback and refine the application's user experience. This iterative process aimed to enhance the overall usability and enjoyment of the fitness application on the INITI playground interactive wall.

Bibliography

1. INITIPLAYGROUND. *Interactive Wall* [online]. 2017. [visited on 2024-04-28]. Available from: https://www.initiplayground.com/.
2. GARAMANTIS. *Interactive Walls – The Right Technology for Every Application* [online]. 2021. [visited on 2024-04-28]. Available from: https://www.garamantis.com/en/blog/interactive-walls-the-right-technologie-for-every-application/.
3. HOYE, Timothy; KOZAK, Joseph. Touch screens: A pressing technology. In: *Tenth Annual Freshman Engineering Sustainability in the New Millennium Conference April*. 2010, vol. 10.
4. LI, Larry et al. *Time-of-Flight Camera—An Introduction*. Dallas, Texas, USA, 2014. Technical White Paper, SLOA190B. Texas Instruments.
5. INARI, T.; AOKI, N. A Proximity Sensor Using Power Variation of a Laser Diode Caused by Returned Light and Its Characteristics of Stability. In: *Proceedings of the 31st Annual Conference of IEEE Industrial Electronics Society, 2005. IECON 2005.* 2005. Available from DOI: 10.1109/IECON.2005.1569230.
6. INTERACTIVEXWALL. *How does the X-Wall work?* [online]. 2019. [visited on 2024-04-28]. Available from: https://interactivexwall.nl/en/how-does-the-x-wall-work/.
7. POWERUPEDU. *Interactive Playground - 3D Camera* [online]. 2013. [visited on 2024-04-28]. Available from: https://powerupedu.com/interactive-playground/.
8. DEVELOPERS.GOOGLE. *Pose Detection ML Kit* [online]. 2023. [visited on 2024-04-28]. Available from: https://developers.google.com/ml-kit/vision/pose-detection.
9. 21STCENTURYAV. *Interactive Video Wall: The Future of Audience Engagement* [online]. 2023. [visited on 2024-01-26]. Available from: https://21stcenturyav.com/interactive-video-wall/.
10. INITIPLAYGROUND. *Our Projects: See Our Playgrounds in Action* [online]. 2023. [visited on 2024-01-26]. Available from eprint: https://www.initiplayground.com/our-projects.

11. INITI. *Playground Project at SIGGRAPH Conference 2017 (L.A.)* [online]. 2017. [visited on 2024-05-07]. Available from: https://www.initi.org/workss/initi-playground-project-at-siggraph-conference-2017-l-a/.
12. METAVERSE, Fashion in. *Tommy Hilfiger Is Experimenting with In-Store AR Try-On* [online]. 2023. [visited on 2024-01-26]. Available from: https://medium.com/@fashioninmetaverse/50ad648539c7.
13. DSTRICK. *Incheon Airport Digital Gym* [online]. 2017. [visited on 2024-01-26]. Available from: https://www.dstrict.com/COMMERCIAL/?q=YToxOntzOjEyOiJrZXl3b3JkX3R5cGUiO3M6MzoiYWxsIjt9&bmode=view&idx=10284355&t=board&category=8pPX38ve12.
14. DESIGNBOOM. *NIKE's Unlimited Stadium in Manila Is the 'World's First LED Running Track'* [online]. 2017. [visited on 2024-01-26]. Available from: https://www.designboom.com/design/nike-unlimited-stadium-manila-worlds-first-led-running-track-05-08-2017/.
15. TEAMLAB. *Drawing on the Water Surface Created by the Dance of Koi and People - Infinity* [online]. 2016. [visited on 2024-01-26]. Available from: https://www.teamlab.art/w/koi_and_people/.
16. JOHNSTON, K. Engagement and Immersion in Digital Play: Supporting Young Children's Digital Wellbeing. *Int J Environ Res Public Health*. 2021, vol. 18, no. 19, p. 10179.
17. ELLIS, Kirsten; BLASHKI, Kathy. The Digital Playground: Kindergarten Children Learning Sign Language Through Multimedia. *AACE Rev.* 2007, vol. 15, no. 3, pp. 225–253. Available online: https://www.learntechlib.org/p/21944.
18. CSIKSZENTMIHALYI, Mihaly. *Flow: The Psychology of Optimal Experience*. Harper & Row, 1990.
19. HYNDMAN, Brendon; TELFORD, Amanda. Active Play: Exploring the Influences on Children's School Playground Activities. *Am J Play*. 2016, vol. 8, pp. 325–344.
20. MYERS, Jonathan et al. Physical Activity and Cardiorespiratory Fitness as Major Markers of Cardiovascular Risk: Their Independent and Interwoven Importance to Health Status. *Prog Cardiovasc Dis*. 2015, vol. 57, no. 4, pp. 306–314. Available from DOI: 10.1016/j.pcad.2014.09.011.
21. COSTA, V.; LUGERT, S.; JAGASIA, R. Role of Adult Hippocampal Neurogenesis in Cognition in Physiology and Disease: Pharmacological Targets and Biomarkers. *Handb Exp Pharmacol*. 2015, vol. 228, pp. 99–155. Available from DOI: 10.1007/978-3-319-16522-6_4.
22. ÅBERG, Maria A. I. et al. Cardiovascular fitness is associated with cognition in young adulthood. *Proc Natl Acad Sci USA*. 2009, vol. 106, no. 49, pp. 20906–20911. Available from DOI: 10.1073/pnas.0905307106.
23. SCHINDLER, Christoph et al. Physical Activity and Cardiovascular Performance – How Important Is Cardiorespiratory Fitness in Childhood? *J Public Health*. 2008, vol. 16, no. 3, pp. 235–243. Available from DOI: 10.1007/s10389-008-0190-0.

24. BYJU'S. *Major Difference Between Morbidity And Mortality*. 2024. Available also from: https://byjus.com/biology/difference-between-morbidity-and-mortality/.

25. LAUKKANEN, Jari A. et al. Cardiovascular Fitness as a Predictor of Mortality in Men. *Arch Intern Med*. 2001, vol. 161, no. 6, pp. 825–831. ISSN 0003-9926. Available from DOI: 10.1001/archinte.161.6.825.

26. JOLLY, Mark A. et al. Impact of Exercise on Heart Rate Recovery. *Circulation*. 2011, vol. 124, no. 14, pp. 1520–6. Available from DOI: 10.1161/CIRCULATIONAHA.110.005009.

27. LAMBERT, Charles P. Strength as a Predictor of Longevity: Compelling Evidence. *J Men's Health*. 2022, vol. 18, no. 5, pp. 1–2.

28. ARAUJO, Claudio Gil et al. Successful 10-second One-legged Stance Performance Predicts Survival in Middle-aged and Older Individuals. *Br J Sports Med*. 2022, vol. 56, no. 17, pp. 975–980. Available from DOI: 10.1136/bjsports-2021-105360.

29. ASSOCIATION, American Heart. *New study finds lowest risk of death was among adults who exercised 150-600 minutes/week* [online]. 2022-07. [visited on 2024-02-06]. Available from: https://www.sciencedaily.com/releases/2022/07/220725105618.htm.

30. BASTEN, D. Gamification. *IEEE Software*. 2017, vol. 34, no. 5, pp. 76–81. Available from DOI: 10.1109/MS.2017.3571581.

31. HAJARIAN, M.; DIAZ, P. Effective Gamification: A Guideline for Gamification Workshop. In: *2021 WEEF/GEDC*. 2021, pp. 506–510. Available from DOI: 10.1109/WEEF/GEDC53299.2021.9657452.

32. DICHEVA, Darina et al. A Course Gamification Platform Supporting Student Motivation. In: *2014 ICWOAL*. 2014, pp. 1–4. Available from DOI: 10.1109/ICWOAL.2014.7009214.

33. CONEJO, Gabriel Guebarra et al. Detailing Motivation in a Gamification Process. In: *2019 ICALT*. 2019, pp. 89–91. Available from DOI: 10.1109/ICALT.2019.00031.

34. LI, Lei; SUN, Qiang. Research on Gamification Learning Model Based on the Flow Theory. In: *2023 CSTE*. 2023, pp. 93–96. Available from DOI: 10.1109/CSTE59648.2023.00023.

35. CODISH, David; RAVID, Gilad. Adaptive Approach for Gamification Optimization. In: *2014 IEEE/ACM 7th International Conference on Utility and Cloud Computing*. 2014, pp. 609–610. Available from DOI: 10.1109/UCC.2014.94.

36. KANKANHALLI, Atreyi. Gamification in Fitness Apps: How do Leaderboards influence Exercise? In: 2015.

37. HAMARI, Juho et al. Does Gamification Work? – A Literature Review. In: *2014 HICSS*. 2014, pp. 3025–3034. Available from DOI: 10.1109/HICSS.2014.377.

38. VRANEŠIĆ, P.; ALEKSIĆ-MASLAĆ, K.; SINKOVIĆ, B. Influence of Gamification Reward System on Student Motivation. In: *2019 MIPRO*. 2019, pp. 766–772. Available from DOI: 10.23919/MIPRO.2019.8756848.

39. YIN, S.; CAI, X.; WANG, Z.; ZHANG, Y.; LUO, S.; MA, J. Impact of gamification elements on user satisfaction in health and fitness applications: A comprehensive approach based on the Kano model. *Computers in Human Behavior*. 2022, vol. 128, p. 107106. ISSN 0747-5632. Available from DOI: 10.1016/j.chb.2021.107106.

40. MEIXNER, Charlotte et al. Gamification in Health Apps to Increase Physical Activity. In: *2019 WiMob*. 2019, pp. 15–20. Available from DOI: 10.1109/WiMOB.2019.8923332.

41. COTTON, Valerie; PATEL, Mitesh S. Gamification Use and Design in Health and Fitness Mobile Apps. *Am J Health Promot*. 2019, vol. 33, no. 3, pp. 448–451. Available from DOI: 10.1177/0890117118790394.

42. FENG, Wenting; TU, Rungting; HSIEH, Peishan. Can gamification increases consumers' engagement in fitness apps? The moderating role of commensurability of the game elements. *J Retail Consumer Services*. 2020, vol. 57, p. 102229. ISSN 0969-6989. Available from DOI: 10.1016/j.jretconser.2020.102229.

43. OZDAMLI, Fezile; MILRICH, Fulbert. Positive and Negative Impacts of Gamification on the Fitness Industry. *Eur J Investig Health Psychol Educ*. 2023, vol. 13, no. 8, pp. 1411–1422. Available from DOI: 10.3390/ejihpe13080103.

44. ARORA, Chirag; RAZAVIAN, Maryam. Ethics of Gamification in Health and Fitness-Tracking. *Int J Environ Res Public Health*. 2021, vol. 18, no. 21. ISSN 1660-4601. Available from DOI: 10.3390/ijerph182111052.

45. GOEL, Gourisha; TANWAR, Poonam; SHARMA, Shweta. UI-UX Design Using User Centred Design (UCD) Method. In: *2022 ICCCI*. 2022, pp. 1–8. Available from DOI: 10.1109/ICCCI54379.2022.9740997.

46. YUA, Ying; XU, Qian. Research on Flat Design Based on UI Design. In: *2021 IPEC*. 2021, pp. 423–426. Available from DOI: 10.1109/IPEC51340.2021.9421257.

47. SHAKURO. *UI/UX Design Trends for 2024*. 2024. Available also from: https://shakuro.com/blog/ui-ux-design-trends-for-2024.

48. NAYUDU, P. Prathap. General Principles of User Interface Design and Websites. *Int J Software Eng*. 2011, vol. 2, p. 45.

49. ALLAM, Allam Hassan; HUSSIN, Ab Razak Che; DAHLAN, Halina Mohamed. User experience: challenges and opportunities. In: 2013. Available also from: https://api.semanticscholar.org/CorpusID:38294117.

50. HASSENZAHL, Marc. *User Experience and Experience Design* [Interaction Design Foundation - IxDF]. 2014. Available also from: https://www.interaction-design.org/literature/book/the-encyclopedia-of-human-computer-interaction-2nd-ed/user-experience-and-experience-design.

51. DEMPSKI, Kelly L.; HARVEY, Brian L. Touchable Interactive Walls: Opportunities and Challenges. In: KISHINO, F.; KITAMURA, Y.; KATO, H.; NAGATA, N. (eds.). *Entertainment Computing - ICEC 2005*. Berlin, Heidelberg: Springer, 2005, vol. 3711. Lecture Notes in Computer Science. Available from DOI: 10.1007/11558651_19.

52. CHEN, Wang; LAO, Song-Yang; LEE, Hyowon; SMEATON, Alan F. Interaction Design for Multi-touch Interactive Walls. In: *2012 Second International Conference on Intelligent System Design and Engineering Application*. 2012, pp. 310–313. Available from DOI: 10.1109/ISdea.2012.596.

53. HIRCHE, Johannes; BOMARK, Peter; BAUER, Mikael; SOLYGA, Pawel. Adaptive interface for text input on large-scale interactive surfaces. In: *2008 3rd IEEE International Workshop on Horizontal Interactive Human Computer Systems*. 2008, pp. 153–156. Available from DOI: 10.1109/TABLETOP.2008.4660198.

54. LUGURI, Jamie; STRAHILEVITZ, Lior Jacob. Shining a Light on Dark Patterns. *J Legal Anal*. 2021, vol. 13, no. 1, pp. 43–109. ISSN 2161-7201. Available from DOI: 10.1093/jla/laaa006.

55. ZAGAL, José P; BJÖRK, Staffan; LEWIS, Chris. Dark Patterns in the Design of Games. In: Foundations of Digital Games 2013, 2013. Available also from: https://urn.kb.se/resolve?urn=urn:nbn:se:ri:diva-24252.

56. MATHUR, Arunesh; KSHIRSAGAR, Mihir; MAYER, Jonathan. What Makes a Dark Pattern... Dark? Design Attributes, Normative Considerations, and Measurement Methods. In: *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. New York, NY, USA: Association for Computing Machinery, 2021. CHI '21. ISBN 9781450380966. Available from DOI: 10.1145/3411764.3445610.

57. GRAY, Colin M.; KOU, Yubo; BATTLES, Bryan; HOGGATT, Joseph; TOOMBS, Austin L. The Dark (Patterns) Side of UX Design. In: *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. Montreal QC, Canada: Association for Computing Machinery, 2018, pp. 1–14. CHI '18. ISBN 9781450356206. Available from DOI: 10.1145/3173574.3174108.

58. DI GERONIMO, Linda; BRAZ, Larissa; FREGNAN, Enrico; PALOMBA, Fabio; BACCHELLI, Alberto. UI Dark Patterns and Where to Find Them: A Study on Mobile Applications and User Perception. In: *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. Honolulu, HI, USA: Association for Computing Machinery, 2020, pp. 1–14. CHI '20. ISBN 9781450367080. Available from DOI: 10.1145/3313831.3376600.

59. WIKIPEDIA CONTRIBUTORS. *Unity (game engine)*. Wikipedia. Available also from: https://en.wikipedia.org/wiki/Unity_(game_engine).

60. HARDING, Greg. *TUIOSimulator Releases*. GitHub. Available also from: https://github.com/gregharding/TUIOSimulator/releases.

61. AWESOMETUTS. *How to Support All Mobile Screen Sizes in Unity*. Available also from: https://awesometuts.com/blog/support-mobile-screen-sizes-unity/?utm_medium=video&utm_source=youtube&utm_campaign=how_to_make_your_game_look_the_same_on_all_mobile_screen_sizes.

62. CHLAN, Matej. *GitLab - BaseInteractive.cs*. Czech Technical University in Prague. Available also from: https://tinyurl.com/mpdv7h4y.

63. ZHANG, Daniel. *Unity Leaderboard Creator*. Available also from: `https://github.com/danqzq/unity-leaderboard-creator`.

Appendix A

List of Abbreviations

BMI Body Mass Index

MTIW Multi Touch Interactive Wall

UI User Interface

UX User Experience

OOP Object Oriented Programming

CTU Czech Technical University

LED Light Emitting Diode

WHO World Health Organization

MET One Metabolic Equivalent

TUIO Tangible User Interface Objects

ITO Indium Tin Oxide

PAT Person, Artifact and Task

TV Television

Appendix **B**

Contents of attachments

- `readme.txt` ..... Brief overview of the file
- `FitnessGame` ..... Build of the application
- `kacervik-InteractiveWalls.pdf` ..... Thesis text
- `src`
  - `FitnessApp.zip` ..... Compressed unity project files
  - `Text` ..... Source form of the thesis in LaTeX
    - `Assignment` ..... Thesis assignments
    - `Images` ..... Images used in thesis
    - `cvutlogobwen.pdf`
    - `cvutlogobw.pdf`
    - `deskyBP_UTF-8_cernobile.tex`
    - `FITcover.cls`
    - `FITthesis.cls`
    - `MasterThesis_example.tex`
    - `mybibliographyfile.bib`