

Digital games and physical rehabilitation of low back pain

A comparative analysis of commercial vs. serious game

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Interest in gamification in rehabilitation has grown due to low adherence to traditional therapy, rising healthcare costs, and uneven access to resources. In general, studies highlight the potential of gamification compared to traditional physical therapy or home exercise, with results that are either similar or superior. Previous studies have used two types of games, commercial and serious games. The aim of this thesis is to examine the differences between these games in the physical rehabilitation of low back pain, which is one of the leading causes of disability worldwide, and to explore from the perspective of games why they are not commonly used in its rehabilitation.

The games chosen for this thesis were based on observations of previous studies which have shown rehabilitation games generally lacking entertainment features, while commercial games are missing essential components for rehabilitation effectiveness. As Nintendo has been utilizing physical movements in their prior games, it was chosen to represent the commercial game and serve as a reference point as a state-of-the-art digital game with their game Ring Fit Adventure. Valedo Motion developed specially for patients with low back pain was chosen to represent the serious game. The games were compared based on technology, user engagement strategies, adaptability, customization and progression in relevance to low back pain rehabilitation.

Analysis of these games show that while both games may pursue the same goal, the interaction between the user and the game can differ significantly. This in turn places limitations on the game's implementation. Aesthetically, the games are not far apart, but the richer gameplay experience offered by Ring Fit Adventure shows how the collaboration between health experts and a major game company has produced a successful gaming experience that also considers individual characteristics that have often been criticized of missing in commercial games. Valedo Motion is a bit more limited from interaction perspective but can be justified based on the chosen approach of measuring trunk and pelvis movements with two attachable body sensors which produce decent gameplay with limited content.

The results show rapid development of the gaming industry, including serious games. However, while Valedo Motion has been studied in several cases demonstrating its usefulness in low back pain physical therapy, the lack of recent information and announcements about the product raises questions. Commercial games can be sold to a larger segment, while for serious games the business is more complex with addressing specific problems with more diverse target audience. Unleashing the full potential of serious games requires multidisciplinary expertise in development but also understanding of game fundamentals to be able to adapt these solutions effectively in the interventions.

Key words: digital games, serious games, physical rehabilitation, low back pain

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1 Introduction

The lack of commitment to conventional rehabilitations, increasing healthcare costs and unfair access to healthcare resources has generated growing interest in applying gamification and game related elements in this context (Alfieri, da Silva Dias, de Oliveira & Battistella 2022). Games commonly referred to as serious games in the context of other than pure entertainment (Bonnechère 2018, 34) can bring challenges for patients as well as provide therapists with tools for the therapy to make rehabilitation a dynamic and attractive process. Many studies emphasize the potential of gamification in comparison to traditional rehabilitation. Compared to conventional physical therapy or exercises performed at home, the results have been similar or superior. An additional benefit has been improved motivation for the exercise program, and the use of this type of technology has also been seen as a cost-effective advantage. (Alfieri et al., 2022.)

In addition to serious games, studies have also used commercial video games and recent studies present positive outcomes in the interventions utilizing commercial games also (Hardy et al., 2015; Damaševičius, Maskeliūnas & Blažauskas 2023). For example, in variety of neurological diseases the Nintendo Wii has been used as a supplement of traditional therapy where it proved significant improvements in key outcomes such as motor performance, balance, executive and cognitive functions (Damaševičius et al., 2023).

Low back pain is the single leading cause of disability in terms of musculoskeletal conditions worldwide. Approximately two-thirds of adults need rehabilitation to low back pain problems that are typically characterized by pain and limitations in mobility which affect the ability to work and participate in society. (World Health Organization 2024, Musculoskeletal health.) Commercial and serious games both offer new ways for patients to be engaged in rehabilitation therapy by enriching the treatment but also at the same time benefitting the caregiver by being a training tool. However, there is a lack of studies comparing serious and commercial games targeted at low back pain rehabilitation.

This thesis aims to address this gap by covering a comparative analysis between two digital games: a commercial and a serious game developed specifically for treatment of low back pain. The goal is to understand through comparison why gaming solutions are not used more widely in physical rehabilitation by examining solutions from a gaming perspective.

1.1 Background

When treating patients with low back pain exercise therapy is often the treatment of choice (Matheve, Claes, Olivieri & Timmermans 2018). These exercises are usually included in home exercise programs which are designed by physiotherapists during in-person sessions to meet the needs of patients and given as printed handouts to encourage patients to take responsibility for their rehabilitation (Lambert et al., 2017). Although exercise therapy with low back pain has proven effectiveness in reducing pain and disability the effect has been considered small to moderate. One of the reasons proposed is that the exercises should be supervised, integrated in functional tasks and tailored to individual needs. Also, the lack of participation in rehabilitation program can be the result of poor motivation, lack of support during home exercises and fear of performing exercises wrong. (Matheve et al., 2018.)

Serious games specifically designed for low back pain rehabilitation can address weaknesses encountered with traditional exercise therapy. Serious games can train new skills, develop knowledge, increase motivation and adherence all in fun and engaging way that can lead to improvement of treatment effects. Also, with the absence of therapist serious games can provide postural feedback and inform patient about correct movement during exercise for example in home environment. (Matheve et al., 2018.)

Research on the benefits of digital games has increased (Damaševičius et al., 2023). This might reflect the development of technology and gaming industry which is fast as more and more advanced solutions are being developed and are available for care givers and patients. Still, the general trend has been that the solution used in clinics are first developed for gaming purposes. These solutions are then adapted to rehabilitation purposes or used directly with patients. (Bonnechère 2018, 145.) While many clinical studies and trials have covered different technologies ranging from commercial games with existing gaming platforms into serious games with specifically developed hardware, the wide range of products doesn't make the choice easy, especially in regards of rehabilitation where the goals can be many.

Also, the field of gamification and serious games is still relatively new, and we are lacking long-term research as the studies usually concentrate on limited interventions and no long-time studies are available of the benefits and how for example interest and motivation have been maintained over a longer period with the help of games. In cases of chronic low back pain exercising for long period of time becomes important and while serious games have the

possibility to increase motivation these effects can also decrease over time. (Matheve et al., 2018.)

1.2 Problem Statement

There are two different types of end users in healthcare environment that serious games can have: patients and healthcare professionals. For healthcare professionals, the use of serious games can be a training tool for practicing sensitive procedures in a safe environment using simulations and video game elements. In addition, serious games offer the professionals a structured way to collect data for more precise analysis. Based on the data analysis the interventions can be planned more precisely considering individual characteristics while also proposing next steps for the intervention. (Vieira, Perrotta & Pais-Vieira 2022.)

In contrast to patient, serious game can offer educational benefits of health topics, target wellness and fitness, be distraction tool for painful procedures or they can be used as a rehabilitation tool in physical or cognitive cases (Vieira et al., 2022). Serious games can also be a training tool to work on developing new healthier behaviours and practices that can be beneficial in the long run in everyday life.

As serious games can be applied in many ways within the field of healthcare both serious and commercial entertainment titles can be used in physical rehabilitation of patients. While serious games appear to have more effectivity in clinical point of view, patients rather prefer the gaming experience of commercial title. (Vieira et al., 2022.) This is interesting and raises a question what are the main differences behind these videogame solutions, and which are the areas that serious games lack in most? In their study Vieira et al. (2022) highlights monetary aspect as one plausible explanation as commercial titles usually have bigger budgets compared to serious game development. This comparative study explores a commercial title Nintendo Ring Fit Adventure and a serious game from Valedo Motion System to find out how wide apart is the gaming experience between these two solutions and what might be the reasons for adopting and not adopting these solutions in rehabilitation intervention.

1.3 Purpose and Objectives

The purpose of this thesis is to examine the differences between a commercial and a serious game used in physical rehabilitation of low back pain and try to understand why games are not used generally. As Adeel, Zia & Fryazinov (2022) state in their study there are three key

rules which are characteristic in rehabilitation games. For keeping the motivation and engagement high, the game needs to be fun to play and enjoyable. Secondly, as rehabilitation is usually a dynamic intervention the game needs to be customizable to allow different exercises based on the needs of the patient. Thirdly, as patient recovers and develops during the intervention a way for recording and documenting the patient's performance is important. (Adeel et al., 2022.) From this point of view the features compared in this thesis are the solutions and their approach, engagement as in gameplay and feedback, customization as in adaptability, and recording performance as in progression and how these exist in the games.

The aim of this study is to be achieved with the following research objectives:

1. Examine the technological solutions available at this point on the market for low back rehabilitation
2. Examine the engagement methods used based on the needs of the user and healthcare professional
3. Examine the customizability, adaptability and progression of the gamified solutions in terms of rehabilitation
4. Identify current pros and cons of adapting these solutions in rehabilitation

1.4 Methodology

In this thesis, a comparative literature review was used to examine two digital games targeted at low back pain. Quoting other studies, Snyder (2019) describes literature review as more or less systematic way of collecting and synthesizing previous research. To conduct a literature review, certain steps need to be taken to which this thesis has utilized the following (Snyder 2019; Research Guides: Research Methods: Literature Reviews 2016):

- Problem formulation
- Literature search
- Data evaluation
- Analysis and Interpretation

When formulating the problem in the first stage the research objective was to differentiate the comparable solutions so that one represents a commercial game and the other represents a serious game. Reason behind this disposition was the observations from previous studies that while both commercial and serious games have been used in rehabilitation, rehabilitation games usually lack the entertainment qualities while popular games lack essential components for rehabilitation effectiveness (Rego et al., 2010). The additional target to concentrate on low back pain rehabilitation was due to its wide contribution to global need of rehabilitation (World Health Organization 2024, Musculoskeletal health).

Through preliminary research of digital games used in low back pain rehabilitation it was identified that Nintendo Ring Fit Adventure had been used in a case study involving low back pain patients (Sato et al., 2021). As the game is targeted specifically for commercial markets and Nintendo has been utilizing physical movements in their prior games, it was chosen to represent the commercial game and serve as a reference point as a state-of-the-art digital game in this thesis. For the serious game example preliminary research identified Valedo Motion which had been developed by medical technology company Hocoma AG specially for patients with low back pain and named a 2015 CES Innovation Awards Honouree while also receiving the highest ranking for adoption potential of wearable sensor products for pervasive care in neurosurgery and orthopaedics (Matheve et al., 2018; Twice.com 2014; Hogaboam & Daim 2018). Due to these mentions it was chosen to represent the state-of-the-art serious game in the context of low back pain.

The thesis focuses on understanding the level of identified solutions in terms of technology, user engagement strategies, adaptability, customization and progression in relevance to low back pain rehabilitation. The goal was to understand through comparison why gaming solutions are not used more widely in physical rehabilitation by examining solutions from a gaming perspective. Forming from the research objectives mentioned in the previous chapter the following key research questions were used to draw a comparative view of the focused solutions.

Research questions:

1. What kind of gaming technology is used in current solutions for low back pain (Ring Fit Adventure and Valedo Motion)?

2. What kind of engagement methods in terms of gameplay and feedback have been used in the solutions?
3. How customizable and adaptable are the gamified solutions in terms of rehabilitation and how does progression exist to support rehabilitation?
4. What are the current pros and cons of adapting these solutions in rehabilitation?

In the second stage due to the lack of direct access to the games, the comparison was based entirely on secondary data collected through searching of articles, web pages, published studies, technical documentation, online multimedia content and gameplay reviews. There were no geographical constraints involved, and the search was carried out entirely in English. The used databases for searching included mainly ScienceDirect, Google Scholar and PubMed among the others. As the study focused on the two example game solutions (Nintendo Ring Fit Adventure and Valedo Motion), physical rehabilitation and low back pain, the literature search in the previously mentioned databases was conducted using primarily these terms in the search query with different permutations. Also, terms gamification, games, digital games, serious games, exergames, rehabilitation and musculoskeletal were used when identifying the solutions for comparison. These search terms were chosen on the basis that they define the research framework in accordance with the objectives. Each example game solution was searched independently using previously mentioned terms. The search results were limited to year 2014 and beyond and screened for inclusion and relevance using the following criteria: (1) The paper can be acquired fully, (2) the language is in English, (3) the paper deals with especially low back pain, and (4) the paper must address the characteristics of games and gamification at least on some level regarding the example games.

With data evaluation the articles were examined manually with the title of the article, abstract and summary. If this failed to provide information on especially the (4) criteria, the entire text was taken to closer examination. Some of the studies were used to find additional studies of interest by using the reference section of the papers. This way, papers that may not appear due to the selected search terms could be included in the research. In analysis and interpretation phases relevant comparison data was extracted from the studies to discuss the findings in terms of gamification and physical rehabilitation. The findings were structured and presented in easily understandable manner to achieve the goal of this thesis.

1.5 Theoretical Framework

This thesis utilizes MDA framework to better understand games as designed systems that build behaviour through interaction. The framework in question is an approach that can be used to analyse properties of games by breaking them down into three components presented below. (Hunicke, Leblanc & Zubek 2004.)

- **Mechanics:** creates system of boundaries with components that players interact with directly e.g. controls, rules, obstacles
- **Dynamics:** describes how players play the game with the boundaries presented by mechanics
- **Aesthetics:** describes the emotional responses that arise when player interacts with the dynamics of the game

For games to support the different outcomes of rehabilitation it is important to understand the mechanics, dynamics and aesthetics and how each of them can support or diminish the intervention (Browning 2016, 117). Game designer and player have each different perspective on these components. While designer considers the perspective from mechanics that causes dynamic behaviour of the system which leads to aesthetic experience, the player experiences the aesthetic tones which arises from perceived dynamics produced by mechanics. (Hunicke et al., 2004.)

Video game's main objective is to entertain people, which usually means having fun. As fun is a subjective feeling there is a more thorough definition needed to describe aesthetics of the game (Hunicke et al., 2004).

Aesthetics can be divided into goals (Hunicke et al., 2004):

- **Sensation:** Game as sense-pleasure
- **Fantasy:** Game as make-believe
- **Narrative:** Game as drama
- **Challenge:** Game as obstacle course
- **Fellowship:** Game as social framework

- Discovery: Game as uncharted territory
- Expression: Game as self-discovery
- Submission: Game as pastime

For example, the football game Fifa could be described with aesthetic components: sensation, challenge and fellowship, while action-adventure game Assassin's Creed could be described fantasy, narrative and discovery, while both games are "fun" to play. Each game can pursue multiple of aesthetic goals and while both serious and commercial games have aesthetics, in commercial game design the emphasis is more on creating enjoyable aesthetics for players to maximize engagement (Browning 2016, 117). Serious games on the other hand focus on different outcomes such as producing useful results in clinical context (Browning 2016, 117).

The aesthetic experiences are created with the game dynamics (Hunicke et al., 2004). For example, in rehabilitation game context the aesthetic goal of challenge can be introduced with physical coordination which in terms can be defined as performing chosen exercises to progress the game. Mechanics support the dynamics by providing the player various actions and control mechanisms within the game context (Hunicke et al., 2004). In rehabilitation game context the main difference in controlling the game is it's done with body movements. This could be achieved with different motion tracking devices and sensors to provide feedback on the movement accuracy or to adjust difficulty in terms of the patient's ability to perform movements.

Browning (2016, 116) has proposed for serious game designers the addition of "outcomes" to extend the MDA framework into MDAO framework. For designing successful serious games, identifying the desired outcomes is critical. Therefore, the process is recommended to start from desired real-world outcomes for the game and progressing from there to adding aesthetics, dynamics and mechanics each designed so that it supports the previous levels. (Browning 2016, 127.) Thus, as the aim of this thesis is to understand through comparison why gaming solutions are not used more widely in physical rehabilitation therefore examining solutions from the perspective of the player (in this case the patient) supports the goal of this thesis.

1.6 Ethical considerations

Digital healthcare has been seen as one solution to the needs related to healthcare accessibility, continuity and efficiency. As a result, the development and use of serious games in healthcare has become more relevant, but it has also raised questions about healthcare ethics. (Aubry & Rusch 2025.) Ethics is the philosophical study of right and wrong, good and bad. In digital healthcare the main ethical principles are bringing benefits and avoiding harm to patients, ensuring equal access to digital health technologies and autonomy in decision making about persons own health (Aubry & Rusch 2025). To ensure that these technologies are developed and used responsibly, there are ethical guidelines and good practices that can be embedded into design workflows.

One of the key components of digital healthcare revolves around health-related data which requires databases for storage but also for analysis. With games there is possibility to collect data of the intervention of rehabilitation for example to assess the patient progress. While different actors in rehabilitation scene can benefit from data collection it also raises question of the collection of the sensitive data but also of the use of the same data. Different countries and regions have different laws and regulations on data management, and therefore depending on where developer and users are, depends on what legal and ethical boundaries there might be. For example, in EU personal data is governed by GDPR (General Data Protection Regulation) in terms of how data is collected, stored and used (Wolford 2025).

The ACM Code of Ethics and Professional Conduct is a set of guidelines that outline the ethical principles and responsibilities to guide all computing professionals while also serving as a remediation if violations occur. It does not solve ethical problems but more precisely it is used as a basis for ethical decision-making. Cases are rarely simple, and multiple principles must be considered. Furthermore, different principles may have different meanings in a case. It is important that the ethical decision-making process is accountable and transparent, thereby maximizing the benefits for multiple stakeholders. (ACM 2018.)

From healthcare point of view the WHO guidance on Ethics & Governance of Artificial Intelligence for Health is an example that outlines how for example gamified solutions should be developed in healthcare (World Health Organization 2021, Ethics and governance of artificial intelligence for health). Even though it addresses from the point of view of AI the ethical principles are also relevant in gamified solutions. Previously mentioned digital

healthcare main ethical principles exist in WHO guidance as it promotes autonomy, transparency, safety and inclusivity.

Ethics cannot just be applied to a solution, but it is a process that must be involved throughout the development. Creating ethically sustainable solutions requires collaboration between different stakeholders, such as designers, developers, regulators, doctors, etc. When solutions are in line with regulations, it also creates trust among consumers and professionals. Technology shapes the society and there exists great responsibility and possibility to make ethical choices.

1.7 Thesis structure

There are seven chapters in this thesis. The remaining sections of the thesis are organized as follows. Chapter 2 describes digital games and physical rehabilitation in general. The focus of the games is from the point of view of physical rehabilitation while also pointing out the difference between commercial and serious games. Chapter 3 presents the comparable solutions one being a commercial and the other a serious game. Chapter 4 describes engagement in the form of gameplay and how it is implemented in the games while chapter 5 discusses the adaptability of the games, and how it supports the rehabilitation of different patient needs. Chapter 6 discusses about the findings and chapter 7 is the conclusion of the thesis.

2 Digital games and physical rehabilitation

An overview of digital games in the form of video games, physical rehabilitation and their connection is presented in this chapter. Video games are dealt with generally and examples of different gaming platforms are introduced while also how video games can be used in rehabilitation is addressed. Although both serious games and commercial games can be used in rehabilitation, they differ in their characteristics. Of these, serious games will be examined. Lastly for games to achieve favourable outcomes in rehabilitation certain elements regarding behavioural change need to be considered.

2.1 Video games

The main objective of video games is to entertain people. Games provide challenges and actions that is referred to as gameplay that entertains. Video games let people do things that are not normally possible in real life which is part of their appeal. Games can also be an art form, making aesthetics part of the design. However, aesthetics is much more than just beautiful graphics. Badly made animation, soundtrack, dialog or artwork can ruin the game even if it has a good gameplay. To name a few; interface graphics, how the game responds to player's button presses, animations, physics of moving objects, speed and accuracy can all have a part in game's aesthetics appeal and considerations. (Adams 2014, 34-36.)

Games have the potential to deepen the experience which is often described as immersion. In 1817 English poet Samuel Taylor Coleridge coined a term called suspension of disbelief which has been used in game industry to mean immersion, as losing track of the outside world while being submerged in a form of entertainment and being unaware of the artificial world that surrounds the experience. In other words, the imaginative reality seems as real as the real world. (Adams 2014, 38.)

Games have the possibility to evoke specific emotions in a player. For this many games incorporate story to support the experience. By mixing the story and game like entertainment players can have the feeling of being inside the story while having an impact in flow of events. Today storytelling has been used so powerfully that many adventure games have been moving away from the formal concept of game into a new hybrid of interactive entertainment. (Adams 2014, 40.)

While gameplay is entertaining by providing challenges and actions as described earlier, to make it more exciting there can be introduced risk and rewards mechanisms. This raises the level of tension making the success or failure more meaningful. Rewards can have many forms such as giving something meaningful like money or key to a locked door or by letting the player advance the story by presenting little bit more of it. Important is that the game should always reward the player of achievement whether it being risky or not. (Adams 2014, 40.)

People tend to enjoy new things to see, do and hear and nowadays video games have the possibility to offer more variety and content compared to earlier forms of games by giving different kinds of worlds to play in but also by changing the gameplay as the game progresses. Progression does not only refer to advancing from level to level, but it can exist within a level with a sequence of challenges that advance towards some kind of goal along a designed path. Players can also be given the possibility of free exploration, but games can also offer learning by adapting to the rules or how to optimize chances of winning. Games typically remain enjoyable as long as they offer something to learn after which they might start to feel boring once the player has mastery of everything and might result in abandonment of the game to pick up something new. In addition, as a way of entertainment players can be given personal choices that affect the gameplay like customization of clothing, vehicles, creatures or buildings which also enriches the role-playing aspect that games offer while socializing can extend the experience and gameplay with friends and family. (Adams 2014, 41-43.)

2.2 Gaming platforms

A wide variety of different gaming machines and platforms are available today. They have different features and performance characteristics such as input and output devices, processor speeds and storage spaces that affect and define the scale of the game. Some games are better suited for certain kind of machine while configuration and physical positioning of the devices affect the suitability between games and machines. (Adams 2014, 109.)

Typical setup when referring to a video game is a home game console that has the player sitting or standing while holding the controller while using a TV as a display. In this setup the player is usually a bit further from the display compared to a computer setup which affects the ability to see small details on the screen leading to the preferred use of simpler and bolder

graphics. Also, because home console can be set up in a person's house they can be used for longer periods of time. (Adams 2014, 109.)

With a home console the input device is usually a dedicated controller while also a large variety of different input devices are available depending on the console manufacture such as steering wheels, balance boards and guitars to name a few. The user interface must be manageable with the controller as the precision is usually weaker compared to for example a computer mouse. When Nintendo Wii was released with its motion-sensitive controller it introduced a new intuitive way of controlling games that resulted it to be used also in unusual contexts such as therapy for injured and elderly people. Another major step was made with Microsoft Xbox and Kinect motion-capture device that was suitable for games requiring physical activity. (Adams 2014, 110.)

Desktop machines running Windows has been one of the most popular options for gaming, as it usually provides detailed graphics with player sitting near the screen and good precision with input devices such as mouse and keyboard allowing also more complex interface design. In contrast portable devices have gained popularity as the computing power has developed enough for games to run on mobile phones and tablets, but the challenge is that these devices differ in terms of screen sizes, processors, operating systems and button layouts to name a few making it difficult to design products. One interesting aspect of portable devices is that the user must support the weight while using it affecting the usability. (Adams 2014, 114-115.)

In the last decade Virtual Reality has evolved from expensive device into more affordable one leading to an increase in popularity for home use (Hamad & Jia 2022). While desktop machines and gaming consoles offer VR headset connectivity also standalone headsets such as Meta Quest 3 are available on the market for deeper immersion producing more life-like gaming experience. VR is more discussed in Section 2.6 as broader whole of Extended Reality covering augmented, virtual and mixed realities in relation to rehabilitation.

A more recent development with gaming is the emergence of cloud gaming services which enhances the gaming experience by resolving challenges that are faced with more traditional ways of gaming. As the game data is computed on a remote server and streamed to the players local device the benefits include consistent and high-quality gaming which is not dependent on the local device performance meaning the user does not have to invest expensive hardware. Also, the compatibility issues between operating systems and hardware are not a concern as

the gameplay is delivered directly to any digital device as well as providing instant access to games. (Su, Lee, He & Chan 2025).

Each of these different categories of game devices and platforms have their strengths and weaknesses. While home game consoles are best used when there is availability of physical space to play in, desktop computers are best when sitting down and used by one person while portable devices must compromise between game complexity for convenience. (Adams 2014, 116.)

2.3 Physical rehabilitation

Rehabilitation has been defined by World Health Organization as “a set of interventions designed to optimize functioning and reduce disability in individuals with health conditions in interaction with their environment” (World Health Organization 2024, Rehabilitation). It helps people of all ages to be as independent as possible in everyday activities by addressing underlying health conditions and their symptoms, modifying environment, using assistive equipment, educating and strengthening self-management, and adapting tasks so that they can be performed more safely and independently (World Health Organization 2024, Rehabilitation). Rehabilitation focuses on the person, which means that the interventions are planned individually and targeted to their specific goals and preferences. There are many places where rehabilitation can take place such as hospital settings, physio- or therapy practices and individual’s homes, school or workplace. (World Health Organization 2024, Rehabilitation.)

Depending on the situation, rehabilitation is usually not performed by a single therapist, but a team of specialists may work with the same patient to meet their needs and goals. However, one of the cornerstones of physical rehabilitation are physiotherapists whom with the patients generally spend most of the rehabilitation time. Important to note is that two people suffering from same disorders might not receive the same treatment because there are lots of underlying factors to be taken into consideration. (Bonnechère 2018, 12.) Therefore, the treatment cannot always be as straightforward as offering the same for everyone, but it must be adaptable and modifiable individually. To achieve the general aim of rehabilitation; restoring or returning person to a state of optimal functioning, different objectives need to be targeted such as posture, balance, strength, coordination, endurance and dexterity (Bonnechère 2018, 14).

As rehabilitation process requires continuous engagement from the patient it can be exhausting due to repetitive nature of exercises. Motivation is essential driver for continuance and by turning rehabilitation exercises into games, patients can be encouraged to perform exercises regularly with a fun way. Motivation can be further enhanced by using basic game elements such as challenges, rewards and competition. In addition, games provide a way to collect data for tracking the progress and making the process more efficient in terms of personalized training while at the same time reducing hospitalization. This all can encourage self-management and help patient to build a habit of beneficial activity.

2.4 Video games in rehabilitation

The traditional video games have usually been played seated while holding the controller in hand making the player rather passive as no other movement is required than tapping the controller. This experience has later evolved with the likes of Nintendo Wii and Xbox Kinect that transformed the player into an active one where the console and new kind of controllers tracked the physical movements of the player to control the game. In physical rehabilitation the patient usually performs different exercises which naturally lead to the interest and integration of these commercial video games into conventional physical rehabilitation about two decades ago (Bonnechère, Jansen, Omelina, & Van Sint 2016).

The Nintendo Wii was released in 2006 being one of the first successful mass market video game console that used motion of the human body (Bonnechère 2018, 5). The console used a controller that detected motion of the player in three dimensions using inertial measurement sensors. Later a Wii Balance Board was released in 2007 that was a force plate that used the displacement of centre of pressure for the controlling of the game. Most games released using these controllers were focused on fitness-related games and body movement. (Bonnechère 2018, 5.)

In domains such as rehabilitation the possibility to evaluate balance and postural control is important (Bonnechère 2018, 5). The way of using centre of pressure is considered as gold standard in balance assessment but the tools are usually situated in laboratory environment and not been transportable outside of the laboratory making access to this tool limited. While the types of Wii balance board offer the solution being portable and providing enough accuracy, the problem is that these kinds of commercial tools do not have the proper validation for clinical use. (Bonnechère 2018, 5.)

Despite the lack of clinical validation, the results have shown that integrating commercial video games into physical rehabilitation programs is efficient and offered in most cases similar results as conventional therapy even though these games are not designed for clinical purposes (Bonnechère et al., 2016). Commercial games have been tested for various pathological conditions in which they can stimulate patient motivation but also used at home to maintain rehabilitation benefits (Bonnechère et al., 2016). Also with the Nintendo Switch that was released in 2017 being the newest addition to Nintendo line, studies show it being safe and feasible exercise tool to be applicable as part of a rehabilitation program in older patients with musculoskeletal conditions as well as providing improvements in gross and fine motor function, cognitive ability, functionality, and quality of life in aging older people with cognitive impairment (Takei, Morita, Watanabe, Suganami & Inao 2022; Zegarra-Ramos et al., 2024).

As condition of patients may vary considerably during rehabilitation the limitation of commercial games may include usability issues among other things. The interfaces are developed for the purpose of entertainment in healthy population neglecting people with disabilities making the self-administering of the game difficult (Jung et al., 2020). This was also noticed regarding Switch console where study demonstrated that the older people participants showed high intrinsic motivation to participate, but they rated the usability of the Nintendo Switch as below ideal (Novo et al., 2025). Also, the holding of separate remote control can be challenging task for patients with fine-motor impairments while calibration processes for tracking purposes may not be easy without the help of assistance (Jung et al., 2020). These limitations can be overcome by developing different controllers that adapt to different limitations, but since commercial games are designed for non-disabled people, using these inventions in the rehabilitation sector usually means adapting an existing solution to the rehabilitation environment rather than vice versa.

2.5 Serious games

In contrast to commercial games, serious games offer solutions to real-world problems (Adams 2014, 43). Entertainment has not been the main focus, but instead, game features have been used to enrich functions found in everyday life. There are many types of serious games, but in this thesis the focus is on healthcare and physical rehabilitation of low back pain.

Gamification serves as an umbrella term for a process where game design elements are incorporated into non-game concepts to motivate and engage people in achieving their goals in contexts such as healthcare, business or education. Elements such as points, badges, challenges, or feedback attempt to improve outcomes in these contexts, while adding entertainment value to a boring activity and providing additional motivational and cognitive benefits. (Damaševičius et al., 2023.) With gamification game elements can be added to an existing system, which provides an easier and more affordable way to integrate the benefits offered by game elements, rather than starting from the problem itself and developing an interactive game to solve it, in which case the product can be referred to as a serious game.

The term serious game is often defined as games designed with a primary purpose other than pure entertainment (Bonnechère 2018, 34). Even though the term “serious” implies that the game itself cannot be fun isn’t the case as Abt (1970) framed in his definition. In healthcare sector and rehabilitation, the term serious gaming can be used to describe the use of commercial games while another term is contraction of exercises and games as exergames which is less used in the literature. (Bonnechère 2018, 34.) The main purpose of serious games is to achieve specific goals, such as education, training, or health promotion. Simulations, role-playing games, and educational games are some of the example forms that serious games can utilize, and which can be used in various settings, such as classrooms, workplaces, and healthcare settings (Damaševičius et al., 2023.)

While the concept of serious games was brought by Abt (1970), military has used gaming already during World War II to improve their image in population (Laamarti, El Saddik, Eid & Thalmann 2014). According to Bonnechère (2018, 34) the term used as today dates to 2002. Before this point in time serious games were developed mainly for educational purposes, but also for advertising, ecology and healthcare (Bonnechère 2018, 34). As there have been proposed many different definitions for serious games in the literature and because the field of serious games is growing at a tremendous pace it has fostered a need for defining characteristics that are important for the design of serious games to have successful products in this field (Laamarti et al., 2014). Below is a list of classification and definitions as Laamarti et al. (2014) proposed:

1. Activity as the type of activity the player needs to perform in the game. These functions are required by the game either as a response or as an input to the game.

- These functions can be such as physical effort, psychological or mental. Examples can be games for well-being or health, rehabilitation, education or training.
2. Modality as the channel through which information is communicated from the computer to the human participating in the game.
 - Usually, sensory modalities experienced in the game like visual, auditory and haptic
 - For feedback a display is a practicable choice
 - Music as an auditory modality has been identified as one of the most important properties that help increase player motivation to exercise while haptic feedback provides realism in rehabilitation games for stroke patients (Laamarti et al., 2014)
 3. Interaction style defines whether the player uses a keyboard, mouse, joystick or some other interface such as brain, eye gaze, movement tracking or touchable interfaces. Depending on the game the choice is important for the success of the game.
 - In movement tracking to feel the freedom and realism the traditional choices may diminish the experience while it can also have shortcomings such as if waving the remote control sitting down is registered as physical exercise.
 4. Environment which can be a combination of several criteria.
 - The environment can be either 2D or 3D or a combination of the two
 - It can be virtual reality or mixed reality that combines real and virtual worlds allowing objects to interact with each other in real time
 - Location awareness can be included depending on if the game allows or needs to know player's current location and mobility to determine if the game is mobile or not.
 - If the game can be played over the internet it can have online environment or social presence if the game is either single or multiplayer.

5. Application area which refers to the different domains that are relevant to serious games, for example educational, advertising, health care, well-being, cultural heritage and interpersonal communication.

The above presented list by Laamarti et al. (2014) provides a broader view and is applicable across multiple domains, while Rego et al. (2010) focused on serious games in healthcare providing categorization based on therapeutic purposes demonstrating how serious games could be used in the context of rehabilitation. Below are classifications that differ in list provided by Rego et al. (2010) and have a definition related more to rehabilitation context (Rego et al., 2010):

1. Application area – the domain application in which a game can be applied. The domain can be very vast but two main applications can be considered: cognitive rehabilitation and physical/motor rehabilitation.
2. Game genre – the genre can vary in relation with the technology used. Amongst other things games to evaluate the movement (catch, reach and grasp) and games that are simulations, strategy, or a combination of several
3. Adaptability (Yes/No) – if the difficulty or challenge in the game is adapted dynamically by the system in relation to performance of the patient.
4. Performance feedback (Yes/No) – if the interaction result is transmitted by the system to the patient. The progress can be measured in achieving goals or in skills over time but also to identify correct or incorrect actions. The results must have a visible meaning and can have multiple modalities (aural, visual, haptic)
5. Progress monitoring – capability of the system to allow saving results of patients' interaction with the system
6. Game portability – while Laamarti et al. (2014) provided mobility in the environment criteria describing if game is mobile or not, Rego et al. (2010) used game portability as the capability of the system to be used at home, hospital or clinic.

In health care sector two games popularized the use of serious games. “Captain Novolin” taught children how to manage diabetes by controlling the superhero’s glucose levels. Another game was “Re-Mission” where children were taught how to deal with cancer treatment by shooting cancer cells to fight the infections and manage clinical signs and

harmful effects. Also, a clinical trial was made to compare the effects of “Re-Mission” and a commercial game Indian Jones and the Emperor’s Tomb with adolescents and young adults undergoing cancer therapy. Results showed that adherence, self-efficacy and knowledge improved playing “Re-Mission”. (Bonnechère 2018, 35-36.)

Interest in utilizing serious games to improve healthcare outcomes has increased and treatments utilizing game-based interventions are increasingly being used in healthcare to promote motivation, engagement, and overall sustainability of health habits. Serious games in addition to gamification is the most common form of game-based treatment in healthcare studies. (Damaševičius et al., 2023.)

2.5.1 In rehabilitation

Serious games can be implemented in various phases concerning rehabilitation (Bonnechère 2018, 114). In early phase such as patient suffering from stroke or severe burns when moving might not be possible at all, the use of mental training and brain imagery to reestablish lost functioning of neural networks can later help with the physical rehabilitation process. In this phase serious games can be used to help the patient to think about the motion they need to perform. (Bonnechère 2018, 115.) Another possibility is the use of electromyography to measure muscle response or electrical activity if patient is still able to control the muscle (Bonnechère 2018, 115). These devices can be integrated into rehabilitation exercises which allows the rehabilitation to really start in the early phase.

Most of the studies cover the integration of serious games during the treatment period of rehabilitation (Bonnechère 2018, 116). The typical development of the patient's motivation during rehabilitation is that during the first sessions of treatment, the patients are motivated and progress until a plateau is reached, and progress may slow down. This may eventually lead to a lack of motivation, or progress can even deteriorate when the exercises are always the same. Considering the motivational point of view integrating serious games in this phase before the fall of motivation is a good option. (Bonnechère 2018, 116.) Another aspect is that in the beginning of the treatment the patients do not need to do that many exercises without the physiotherapist and the sessions are close to one another. Then increasingly the sessions get more spaced, and the patients need to perform the exercises at home which is known that only 30% of patients do. (Bonnechère 2018, 116.) The serious games can be integrated progressively during the sessions with the help of physiotherapist and then being installed at

home to provide motivational aspect. Also, the games can help in correcting the movement patterns while also providing feedback for patients and clinicians. (Bonnechère 2018, 117.)

Lastly, after the treatment is often the phase where patients do not perform exercises anymore (Bonnechère 2018, 117). In this phase the motivational point of view becomes an important aspect again while the serious game can also act as a reminder to perform some exercises. In addition, the games can be equipped with visualization tools to allow follow-up of the progress to motivate the patient onwards. (Bonnechère 2018, 117.)

2.5.2 Potential towards low back pain

The largest contributor to the overall burden of musculoskeletal disorders is low back pain (World Health Organization 2024, Musculoskeletal health). Number of people suffering from musculoskeletal disorders increases rapidly with age, but the associated functional limitations are important throughout life. Within all age groups musculoskeletal conditions can rise suddenly due to an injury, or they can be long-term conditions such as chronic low back pain or osteoarthritis. (World Health Organization 2024, Musculoskeletal health).

Musculoskeletal diseases can be treated with exercises using gamification, virtual reality, and augmented reality, which are usually attractive from the patient's perspective (Alfieri et al., 2022). In the context of musculoskeletal rehabilitation serious games consists of systems measuring how the patients move providing with guidance to execute specific movements in playful manner. In certain rehabilitation exercises they assist clinicians with collecting movement data reducing the need of constant supervision while enhancing patient's adherence. The potential lies in improving clinical outcomes, reducing costs and making accessibility to rehabilitation programs easier. (Favre, Cantaloube & Jolles 2023.)

Movement as the key component, is measured with devices such as cameras, inertial measurement units (IMUs), electromyographic (EMG) and force sensors providing movement quality and quantity in serious games. After processing the data, it can provide detailed information on many biomechanical parameters such as the range of motion, number of repetitions, technique, muscle activity and trajectory of the centre of pressure. With the data clinicians can gain specific insights to optimizing treatment strategies for individual patients while for patients they can provide feedback on movement executions. (Favre et al., 2023.)

However, it is also important to note that, although serious games have been specifically developed for a target purpose, many studies have not reported significant differences in

clinical outcomes compared to traditional exercises. Nevertheless, they have been considered beneficial primarily because they increase engagement and their possibility to deliver high-quality care at lower costs, contributing to improved access and efficiency in healthcare. (Favre et al., 2023.)

2.6 Extended reality

Extended reality (XR) is an umbrella term covering Augmented Reality (AR), Virtual Reality (VR) and Mixed Reality (MR). Its application to serious games has been a subject of interest for years. In healthcare sector it can provide opportunity to develop several kinds of tools and applications that can improve the quality and efficiency of care and services for professionals and patients. Applications ranging from surgical planning and medical training that simulate different scenarios are some of the examples in healthcare domain. (Condino, Gesi, Vigliani, Carbone, & Turini 2022.)

All these extended realities have been used in musculoskeletal rehabilitation by enriching biofeedback data to provide even more advanced guidance to patients while providing an immersive and interactive experience. For complex exercises and movements that need to be performed precisely, XR plays an important role in communication with the patients. There are various devices that can be used to deliver XR, with display, tablet or headset being the most common. (Favre et al., 2023.)

Extensive visual feedback has been shown to benefit motor learning and promote engagement. Avatars or graphics can be used to guide the patient's movements, while sounds can provide instructions, feedback and auditory cues, and haptics can be used to enhance multisensory experiences. In addition, performance metrics can be added to provide quantitative data on different parameters to help patients track their progress. (Favre et al., 2023.)

Regarding chronic low back pain VR has demonstrated value in pain reduction by drawing the user's attention to tasks. One of the key benefits of VR is to actively participate the patient in the therapeutic process with intrinsic motivation whereas conventional methods can lead to boredom or lack of interest. VR provides a simulated environment where various postures, movements and situations could be observed by adding additional devices to the patient's body that provide detection to help therapists and patients themselves to observe the form of the movement. (Morone et al., 2024.) Healthcare domain has become one of the biggest

adopters of extended reality. But with their many benefits there are still issues and side effects that need to be resolved and understood for the full benefit of these technologies such as “cyber sickness” and compatibility with general population. (Condino et al., 2022.)

2.7 The challenge of behavioural change

Long-term behavioural change is the main goal of most clinical interventions (Browning 2016, 112). In healthcare setting gamification is argued to encourage behavioural change with patients, promote self-management of chronic conditions, support commitment to treatment and increase the supervision of patient (Al-Rayes et al., 2022). The primary reason behind behavioural change is that gamified solutions can create intrinsic motivation compared to relying only on extrinsic motivations (Browning 2016, 106). Deci and Ryan (2000) define intrinsic motivation as essential satisfaction and enjoyment caused by an activity and extrinsic motivation as commitment to an activity because it leads to a favourable outcome (Browning 2016, 106). In gamification context intrinsic motivators are such as solving challenges and mastering skills to provide a sense of accomplishment whereas extrinsic motivators can be external rewards or pressure like points and badges and leaderboards. (Browning 2016, 106-107.)

Nevertheless, affecting persons behaviour change is more complicated than only providing information about for example favourable outcomes. To create behavioural change, many serious games have focused on raising awareness of their target problem, which alone can lead to a failure to utilize the game's true potential in this regard (Browning 2016, 113). For example, knowing the beneficial effects of exercise and having like-minded people around, the person can still fail to follow exercise plan if it is felt too difficult or not fit in schedule (Browning 2016, 113). To achieve favourable outcome the person must feel capable of the behaviour to adopt it which brings self-efficacy as an important element to acknowledge in the design process (Browning 2016, 113). One of the greatest strengths of serious games is to build self-efficacy (Browning 2016, 118).

According to Ajzen (1985), Schwarzer (1992) and Rosenstock (1974), self-efficacy is experienced during the flow state that can also increase the likelihood of long-term behaviour change (Browning 2016, 112). Csikszentmihalyi (1997) defines "flow" as a state of deep concentration, accompanied by a sense of control, loss of self-awareness, and an altered sense of time, that can occur when a person is fully engaged in the challenge of a game (Browning 2016, 111-112). One of the most effective tools for creating engaging gaming experiences is

the ability to get the player into a state of flow (Browning 2016, 112). According to Gregory (2008), when an experience offers the participant a clear goal, immediate feedback on their actions, and appropriately challenging tasks, it is possible to achieve a sense of flow (Browning 2016, 112). Matching the difficulty of the activity to the participant's skill level is a key factor in achieving flow. A level that is too easy can lead to boredom, while a level that is too difficult can cause frustration or stress. (Browning 2016, 112.) Proffitt (2016) argues that in typical games for entertainment the difficulty between levels when progressing the game is similar to all players which in dynamic rehabilitation is not optimal. Patients with different backgrounds and situations recover and progress in different rates. With slow progression, patient may remain in the same level for long periods of time before advancing further which can also result in boredom or abandonment of the game. (Proffitt 2016.) The benefit in games is that they provide a choice to the player of the difficulty setting but are also able to change difficulty in response to player's performance. When the challenges are appropriate to the participant's skill level, and they have a sense of control over the outcome of the events, this has a positive impact on self-confidence and self-efficacy. (Browning 2016, 112.)

3 Comparable solutions

This chapter describes the devices and platforms that are used in the comparable solutions. Because rehabilitation can take place in many places, such as a hospital or at home, the wide range of different gaming devices on the one hand offers flexibility and possibilities, but on the other hand can limit the gaming experience itself. Rehabilitation that takes place permanently in one place, such as in a hospital or clinic, allows for a permanent setup for the gaming device. In this case, the size of the device might not be as important, which also allows for a more complex configuration, which can be seen as features that improve technical quality. In this case, there is also likely to be enough open space available. One of the requirements for rehabilitation that takes place at home can be the easy portability and installation of the device. The space available for using the device may then be more limited, in which case a compromise may have to be sought in the balance between the technical features and the physical size of the device.

Since rehabilitation usually consists of physical exercises, the controllers need to be able to track physical movement to provide feedback as well as convert it to gameplay. In terms of accuracy, on the one hand, precise measuring instruments are needed, but on the other hand, more affordable instruments can provide sufficient results (Bonnechère 2018, 134).

Additionally, an important aspect when applying these systems is the cost of the technology. The accuracy, type and number of sensors combined with the setup requirements are issues that affect the usability in private and the public sectors. Also, the lack of common line approach makes the applicability of exergaming challenging in general. (Morone et al., 2024.)

3.1 Nintendo Ring Fit Adventure

Ring Fit Adventure is a fitness role playing game published by Nintendo for the Nintendo Switch video game console. The Switch console itself is a combination of a console and portable device as it runs on a tablet type of device which can be used as a standalone device or connected to a dock station through which the image can be ported to a TV screen. The Switch console and game controller can be seen from Figure 1.

The game itself includes two physical components which are illustrated in Figure 2: a leg strap which is attached to players leg and a ring-shaped large resistance ring (Ring-Con) that the player holds. To each of these a controller (Joy-Con) is connected to measure and track movement.



Figure 1. Nintendo Switch console with dock station and controller. Picture: <https://www.nintendo.com/my/hardware/detail/switch/index.html>

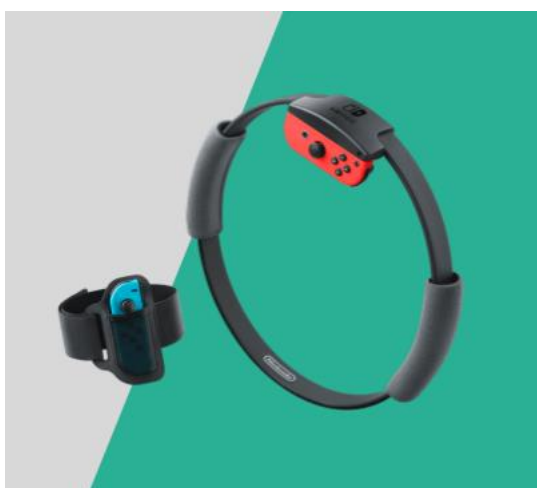


Figure 2. Ring Fit Adventure controllers, Ring-Con and Leg Strap. Picture: <https://ringfitadventure.nintendo.com/#ring-con>

The Ring-Con has a high-sensitivity force sensor that detects force from players pushing or pulling on the controller. Furthermore, the Joy-Con controller has an accelerometer and gyroscope that detects a variety of movements, such as spinning and tilting. The other controller inserted in the leg strap and attached to left leg utilizes its accelerometer and gyroscope to measure lower body movement, in the form of steps and knee bends. (Frequently Asked Questions | Ring Fit Adventure | Nintendo Switch | Nintendo, 2025.)

Player advances in the game by stretching and squeezing the controller. Fitness movements are recognized and detected by a force sensor and transformed into actions linked to the

player character on the screen. The heart rate of the player is monitored by infrared rays of the controller. With feedback from these the game itself estimates the optimal exercise intensity for each player and upgrades or downgrades accordingly. (Sato et al., 2021.)

In the scope of rehabilitation, Nintendo Switches portability makes it capable to be used at home, hospital or clinic environment. As space is needed to perform the exercises the size of the device and its versatility with connection methods supports the rehabilitation environment.

3.2 Valedo Motion

The Valedo Motion is a certified medical device and rehabilitation tool for patients with low back pain (Matheve et al., 2018). It has been developed by medical technology company Hocoma AG and named a 2015 CES Innovation Awards Honouree while also receiving the highest ranking for adoption potential of wearable sensor products for pervasive care in neurosurgery and orthopaedics (Twice.com 2014; Hogaboam et al., 2018).

The Valedo System comprises of two wireless sensors that are attached to persons body to measure trunk and pelvis movements (Valedo User Manual 2018). The sensor is illustrated in Figure 3 and the placement of the sensors can be seen from Figure 4. The sensors are attached with either double-sided medical tape or a specially designed belt. The sensors information is transferred to a computer with a Bluetooth connection. The movement signals are analysed and used to provide accurate real-time functional feedback of essential muscle groups in the pelvic and lumbar regions in a game setting of how the movements are done and if they are done correctly. The system monitors the movement performance and guides through exercises specifically designed for general low back pain therapy while enhancing movement awareness without the necessary presence of a therapist. (Valedo User Manual 2018.)



Figure 3. Valedo Motion sensor. Picture: <https://www.amazon.ae/Valedo-30811-Digital-Back-Therapy/dp/B0100ONKPM>

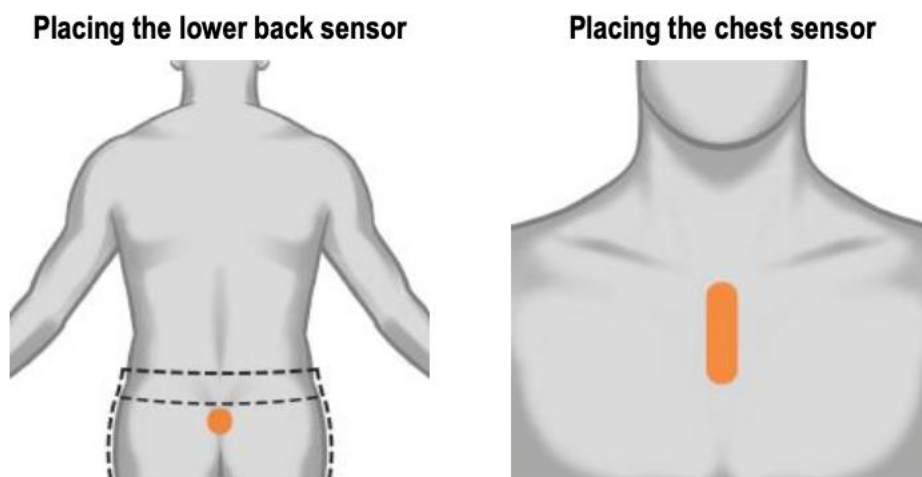


Figure 4. Placing the Valedo Motion sensors. Picture: Valedo User Manual 2018.

In addition to the sensors the patient uses their own computing device which can be a tablet or a laptop for example. A standard Valedo application is provided for lower back therapy as a free download but as of writing this thesis the official website (www.valedotherapy.com) is inactive and the address forwards to Hocoma AG home page.

In the scope of rehabilitation, Valedo's portability makes it capable to be used at home, hospital or clinic environment. Valedo's game can be run on tablet or laptop and it can be used almost anywhere which supports the rehabilitation environment.

4 Engagement

In physical rehabilitation setting an engaging gameplay can help patients stay motivated and committed to therapy. As discussed earlier the main objective of video games is to entertain people and at the core of this is the gameplay. In the case of serious games, the focus is shifted from entertainment into solving real world problems. With physical rehabilitation, the intervention also presents another way of interacting with the game, so it is relevant to consider the gameplay aspect to understand how it affects the experience and what to consider when designing games for rehabilitation.

4.1 About gameplay

The gameplay consists of the player who plays the game and of two key components being user interface that presents the game to the player and the core mechanics that implement the rules and the algorithms behind the rules formulating the game AI (Adams 2014, 51-52). The task of core mechanics is to generate the gameplay by defining challenges and actions (Adams 2014, 51). Challenges are the immediate goals of the game that the player must face to reach the final object of the game (Adams 2014, 27). There are several types of challenges that video games can offer, such as physical coordination, logical challenges, pattern recognition, time pressure, memory and knowledge, exploration, conflict, economic, conceptual reasoning, creation and construction (Adams 2014, 35-36). Basically, a challenge can be any task that is nontrivial but not too difficult to accomplish by the player requiring either mental or physical effort. (Adams 2014, 27.) In an example of action video games enemies are frequently faced and defeated after which in the end a final boss might be waiting. While the largest challenge in a game is achieving its final goal, it can be defined with smaller challenges that are scattered along the way, or they can be used as optional challenges to provide more content or practice for the player. (Adams 2014, 27.)

To overcome challenges and reach the final objective of the game player takes actions (Adams 2014, 27). Some of these actions are mandatory under certain circumstances, but in situations where actions need to be either allowed or prohibited, set of rules can be defined. There can also be optional actions that primarily add to the enjoyment of the experience. As video games are digital mediums every action that is allowed needs to be built into the game which limits the range of actions to choose from when facing a challenge. (Adams 2014, 27.)

Entertainment is also an important part of gameplay which requires imagination and fantasy through the act of pretending (Adams 2014, 27).

The user interface transforms the above-mentioned core mechanics into graphics and sounds. In addition, the players button presses of the controller are transformed into actions within the game. Compared to some other computer software that is usually used as a tool of some kind, such as web browsing, painting, or word processing, the user interface of a video game has a more complex role. While other software must present the work clearly and effectively, in the case of a game, the challenges of the game hinder the player's action and may, for example, hide information and only reveal it as the player progresses, but it must also be able to entertain and remain simple. (Adams 2014, 51.)

The user interface can be further divided into two different features being interaction model and camera model (Adams 2014, 52). The interaction model determines how the player interacts with the game world. Traditional ones can be such as avatar-based where player is represented by a character inside the game world or omnipresent where the player has a god-like perspective like for example in *The Sims*. A game can also have more than one interaction model depending on the situation at a given time. The camera model displays the physical space of the game world from a particular angle or point of view. It can also be static with the camera showing the space from a fixed or dynamic perspective moving in response to players actions making the experience livelier and more cinematic. Most used camera models are first person and third person in a 3D environment and top-down and side-scrolling in a 2D environment. (Adams 2014, 52-53.)

In addition to user interface and core mechanics a third component can be considered as storytelling. It is an integral part and can add significantly to the entertainment value of the game and keep players interested longer periods of time but also in commercial games it can attract wider audience and help to sell the game (Adams 2014, 205). Storytelling is a wide and interesting topic consisting of many elements. In brief the storytelling engine interweaves the gameplay with the narrative events of the story creating a coherent whole where events feel related to each other forming a continuous story that entertains the player and raises the experience to another level (Adams 2014, 215). There can be narrative blocks used to tell parts of the story that can take many forms such as cut scenes, scrolling texts or voice-over commentary. As games are active processes there is a fine line between balancing the narrative and gameplay aspects. (Adams 2014, 212.) Although storytelling can provide

engaging gameplay, deeper emotional response and greater satisfaction, storytelling engine is not mandatory and can be left out if the game isn't telling a story. (Adams 2014, 244.)

4.2 General gameplay of Nintendo Ring Fit Adventure

The interaction model used in the game is avatar-based where player is represented by a character inside the game. The Camera mode is from a third person view as illustrated in Figure 5. Player tightens the leg strap in place and holds the Ring-Con in front like a steering wheel. By jogging on the spot, the player moves through the levels in a fixed path. From time-to-time various obstacles appear that require different movements to get past. To jump the Ring-Con can be pointed down and squeezed while going upstairs requires player to raise knees higher when jogging. Coins are collected by stretching out the Ring-Con and obstacles are destroyed by squeezing the Ring-Con. Later, the movements continue to develop further into squats to jump higher and twisting the body while pressing the ring against the abdomen to paddle a boat or holding the ring above head while sliding ziplines. Levels in the game can last from 2 to 10 minutes each. (Webster 2019.)



Figure 5. Ring Fit Adventure in-game screen. Picture: <https://www.nintendo.fi/nintendo-switch-perhe/pelit/ring-fit-adventure>.

While running through the levels that consist of colourful variations of outdoor, forested regions and indoor, enemies appear along the trail. By colliding with them the player enters a battle screen with turn-based manner as illustrated in Figure 6. When attacking player selects

from number of different exercises, for example squats, and then does repetitions inflicting damage to enemies. (Webster 2019.) The different type of exercises has each been selected under the supervision of a personal trainer and a yoga instructor (Frequently Asked Questions | Ring Fit Adventure | Nintendo Switch | Nintendo, 2025). When defending enemy attacks the Ring-Con is held against the abs and squeezed for the duration of the attack to create a shield. This process continues until health is depleted. (Webster 2019.)

A layer of strategy is implemented with colour coding different exercises to match the enemies. The idea is to match the colours to be able defeat the enemy more easily which comes in handy with bosses as they have bigger health bars. More exercises are unlocked while advancing which brings variety in players toolbox. Also, after each day the game asks if player wants to increase the challenge or keep it the same. (Webster 2019.)

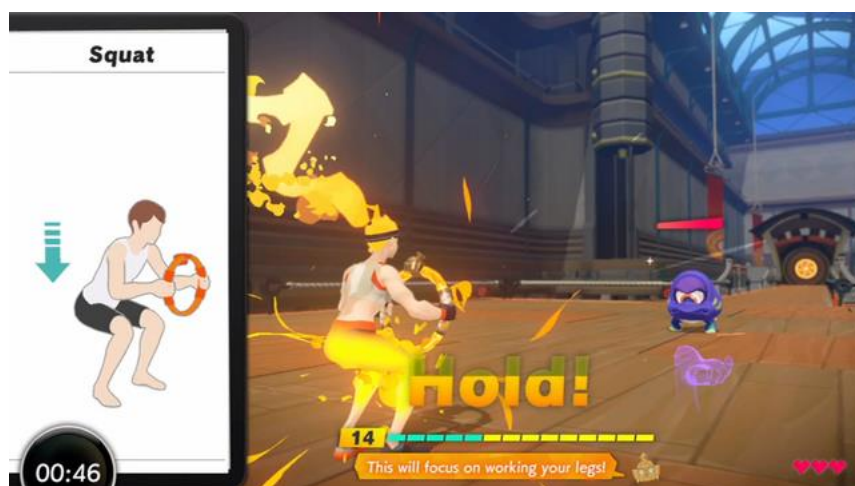


Figure 6. Ring Fit Adventure in-game screen of battle scene. Picture: https://www.ign.com/wikis/ring-fit-adventure/Fit_Battles.

There has been put much effort to the storytelling. At the start of the game player is provided an introductory cutscene to motivate and embark on the adventure where also the main cast of characters are introduced. The player finds a magic ring and releases a demon called Dragaux by interacting with it. Player is tasked with defeating the demon and recovering the lost rings of powers. As the story unfolds, Dragaux was once rings friend but turned evil after being possessed by dark power and thus the ring wants to help the demon. During gameplay the demon keeps taunting player to motivate the player in defeating him. (Macák 2021.) The ring is used as a fitness companion on the journey to prevent the evil plan. Other character designs in the game are based on anthropomorphized exercise equipment. (Dornbush 2019.)

While the main hook in Ring Fit Adventure is the story mode, the game also provides various minigames. Minigames are usually variations of exercises with unique visual setting. They can consist of variations of squats, shooting air blasts into targets by squeezing the ring or trying to do exercises as well as possible. Minigames are not mandatory, but they offer additional in game currency or items. From items players can craft smoothies which can be used as healing or changing attacks to a different colour. The crafting is also done by pressing the ring which mimics squeezing the fruits into the smoothie. (Macák 2021.)

4.3 General gameplay of Valedo Motion

Like Ring Fit Adventure, the interaction model used in the game is avatar-based where player is represented by a character inside the game. The Camera mode is also from a third person view. Patients practice postural movements with feedback from the game while also controlling the game with the postural movements. In Meinke, Peters, Knols, Karlen & Swanenburg (2021) study the patients used five movements to control the game. These were moving the trunk in a frontal plane, sagittal plane and transversal plane. In addition, hip movements were performed in frontal and sagittal plane. In each exercise, the body or hip had to be moved in one plane, or the movements had to be alternated in different planes. The sensors were installed on the back and on the chest of the patient and they measured trunk and hip movements on different planes. (Meinke et al., 2021.) The exercises are adapted to the range of motion of the participants and can be saved in a user profile inside the game. The assessment can be repeated at any time while progression and difficulty are determined by the Valedo app. (Meinke, Peters, Knols, Swanenburg, & Karlen 2022.)

Player's movements are shown continuously with an avatar on the screen of the tablet relative to the movement goal. The goal can be displayed for example as a white track to follow, as circlets to fly through or collecting crystals by performing movements as accurately as possible. The postural movements can be seen from Figure 7 and the in-game screen from Figure 12 where the track is followed by travelling through the circlets. Player also receives auditory feedback in addition to visual feedback when the track is matched precisely and when gathering crystals. After the exercise is completed the ranking of the 10 best previous attempts are shown to the player. (Meinke et al., 2021.) Other game options include a cave diver game for pelvic control movements in the sagittal plane and fruits for pelvic movements in the frontal plane which are illustrated in Figure 8. For 3D pelvic movements the options are Glider, Maze, Colours and Golf games illustrated in Figure 9. For postural feedback during

functional motor control exercise a coconut game can be used where the difficulty of the game is adjusted by allowing less lumbar movement before the coconuts fall off the tray as illustrated in Figure 10. (Matheve et al., 2018.)

The inclusion of storytelling in the game has not been discussed in more detail in the sources found but Valedo offers a home screen which can be seen in Figure 11 where user is directed to after initial setup. It consists of a village the user is free to explore. The houses represent the exercises that can be done. The more exercise is done the more houses are unlocked and the more village grows in height and appearance. The objective is to build houses and unlock new movements and districts with gems collected from completing the exercises. The size of the houses indicates the level of difficulty that has been achieved so far in given exercise. (Valedo User Manual 2018.)



(A) Setup during exercises with postural feedback

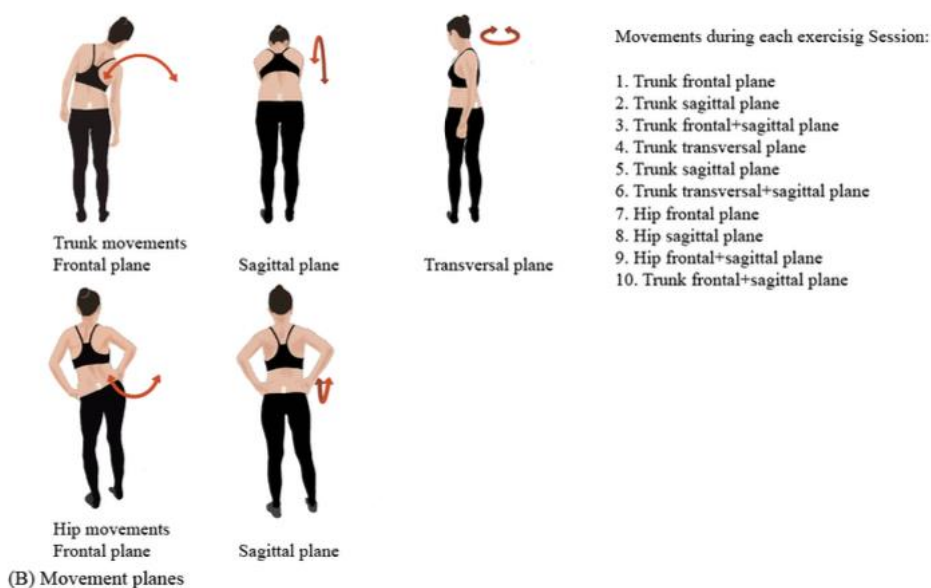


Figure 7. Exercises and controlling the games. Picture: Meinke et al., 2021.

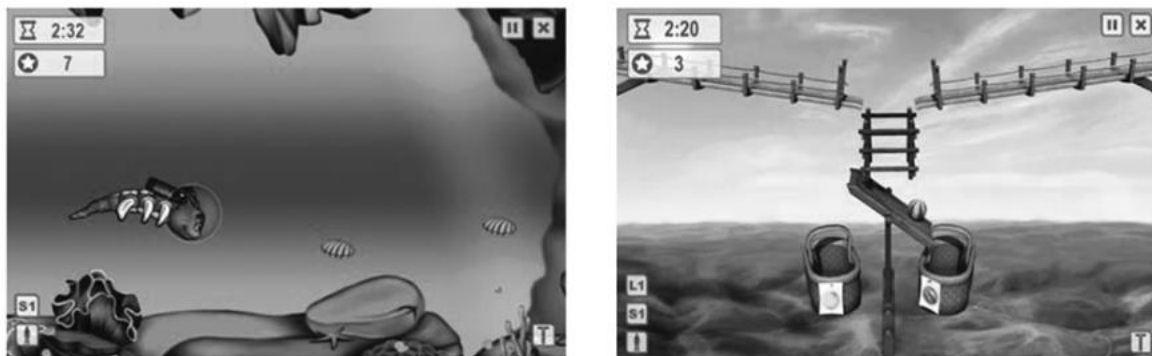


Figure 8. Cave diver and fruits game. Picture: Matheve et al., 2018.

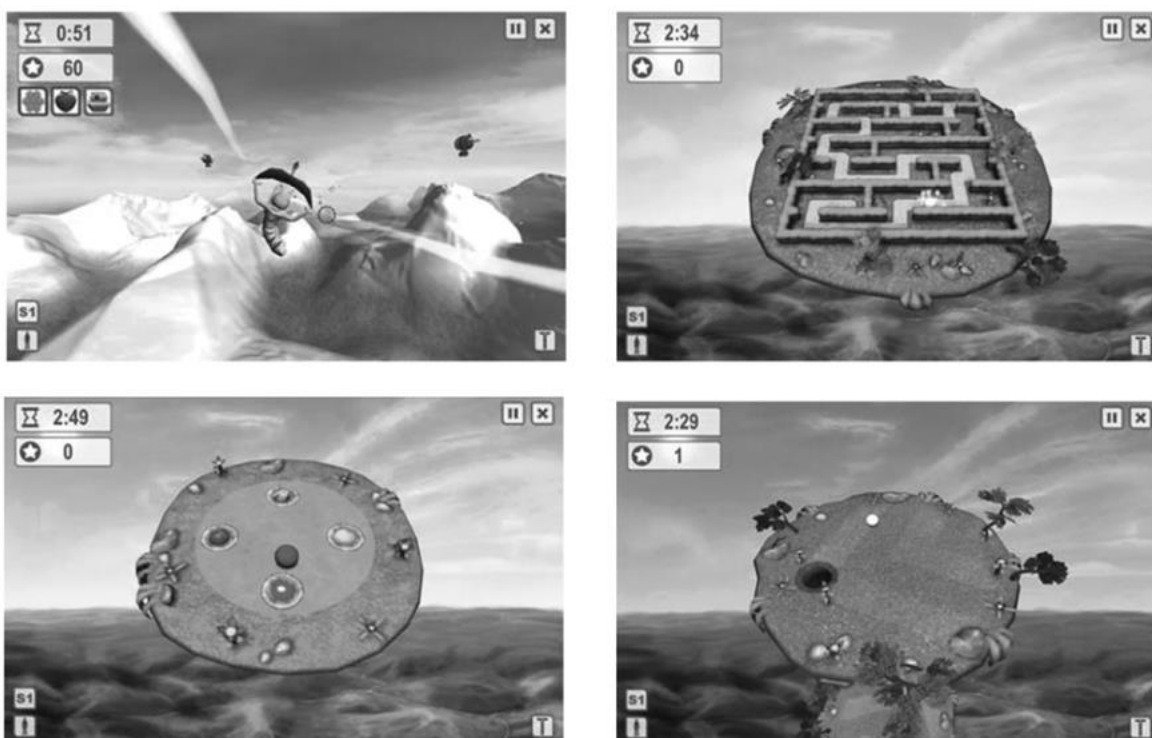


Figure 9. Glider, Maze, Colours and Golf games. Picture: Matheve et al., 2018.

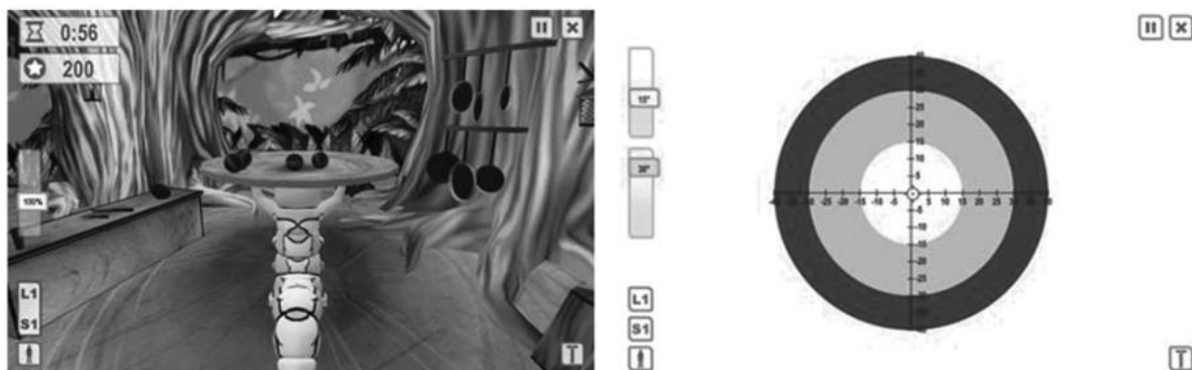


Figure 10. Coconut and target game. Picture: Matheve et al., 2018.



Figure 11. Home screen of Valedo Motion. Picture: Valedo User Manual 2018.



Figure 12. In-game screen. Picture: <https://appadvice.com/app/valedo/863104705>.

4.4 Feedback

With the absence of therapist serious games can provide postural feedback and inform patient about correct movement during exercise for example in home environment (Matheve et al.,

2018). It is an important aspect in rehabilitation context to both patients and caregivers. In addition to supporting correct movements the benefits can be the possibility of gathering data of the interaction which can be helpful to follow the progress of patient but also to provide personalization. While both games, Ring Fit Adventure and Valedo can transmit the result of the interaction to the patient there is also another important usage for feedback and that is retaining users' attention.

When playing a game players like to feel successful for which feedback is an effective method that should be encouraging, positive and rewarding. In healthcare patients are typically tasked with movements that are challenging to them because of the underlying condition that is being treated. In this context the in-game feedback should reward the effort and engagement instead of promoting only perfect performance. In commercial games the rewards usually outweigh penalties. (Ushaw, Davison, Eyre & Morgan 2015.)

There are two types of reward schemes that can be implemented. With long term goals the player can be encouraged with feedback towards ongoing participation of the (rehabilitation) game. A general method in gamification is to implement achievements where the player is awarded when reaching specific goals such as high scores or hours played. In commercial games different achievement types can be scattered throughout the game's lifetime to be awarded relatively regularly. (Ushaw et al., 2015.)

The other mechanism is to provide the player constantly positive encouragement during the minute-to-minute gameplay loop. This has been identified important in commercial games with good example of Nintendo's Mario games where coins are collected throughout the levels. In healthcare, this could be visual or audio effects that occur in conjunction with the player's actions when they are in line with the goal. Generally, healthcare games aim to promote continued engagement, so the more rewarding the experience, the more likely the player will continue. (Ushaw et al., 2015.)

There can also be downside if gamification is used wrong. Browning (2016, 106-107) argues that it is often seen that non-game activities are tried to be made more engaging by thrusting game-like elements as reward systems such as achievements, points and leaderboards. These elements serve a beneficial purpose as feedback mechanisms in games and adding them to gamified experiences strengthens them as an extrinsic reward system. Deterding (2010) argues that it has harmful effects on long-term behaviour change as extrinsic motivation does not create the same positive intrinsic motivation as a well-designed game (Browning 2016,

107). Kohn (1993) states that while it may give short-term motivation, in long-term it can be felt as unsatisfactory and have negative effect on the whole experience (Browning 2016, 107). According to Browning (2016, 107) as games can put players into a playful mindset through which intrinsic motivation is generated, thus only adding game-like features represents a misunderstanding of the characteristics of a satisfying game.

As feedback mechanisms can enhance the engagement it is reasonable to investigate the level of gamification elements found in each of the game in this thesis. Similarly, as in study by Vieira et al. (2022) a list of gamification elements was used based on a premade list presented by Sienel, Münster, & Zimmermann (2021). The list is presented in Appendix 1 as Table 2, along with definition for each gamification element as collected by Vieira et al. (2022).

It is important to notice that in this study the games were evaluated according to the game descriptions available in selected papers and the internet. In the case of Valedo (serious game) sources were extremely limited. Therefore, the assumptions are based on studies applying the solution. Since the games were not accessible at the time of writing, this may mean that not all possible gamification elements have been identified, even if they exist. Nor has it been possible to verify their existence or lack through gameplay. Results of the analysis of gamification elements in Nintendo Ring Fit Adventure and Valedo is provided in Table 1.

Table 1. Gamification elements found in comparison.

Gamification elements are marked as present if they exist in corresponding game.

	Nintendo Ring Fit Adventure	Valedo Motion
Achievement Symbol	Present	Present
Assessment	Present	Present
Avatar	Present	Present
Brag Button	- (Not in game but in console present)	-
Challenge	Present	Present
Choice	Present	Present
Collection Set	Present	-
Crowning	Present	-
Difficulty Selection	Present	Present
Discussion-board	-	-
Feedback	Present	Present
Gift	-	-
Leaderboard	Present	-

	Nintendo Ring Fit Adventure	Valedo Motion
Level	Present	Present
Number Limit	Present	Present
Performance Graph	Present	Present
Permadeath	-	-
Points	Present	Present
Prize Pacing	Present	-
Progress Bar	Present	Present
Record	Present	Present
Reward	Present	Present
Schedule	-	-
Social Feedback	- (Not in game but in console present)	-
Social Graph	-	-
Team	-	-
Time Limit	Present	Present
Torture Break	(As a suggestion)	-
Unlocking	Present	Present

5 Customizability

Rehabilitation should be adaptable according to different patient needs which underlines the importance of customization as well as calibration. With commercial games this can be challenging as different parameters might not be possible to modify. Commercial games serve general population and using these solutions means usually that the rehabilitation is adapted to the game features rather than vice versa. In the case of serious games, the primary purpose is to accommodate the need of rehabilitation. Under therapist supervision the parameters of the game can be controlled by clinician, but in home setting the challenge is different. (Bonnechère 2018, 133-135.)

5.1 Adaptability (Nintendo Ring Fit Adventure)

As Ring Fit Adventure is designed to be a fitness game it provides possibility to choose exercises that suit to players goals and set repetitions, difficulty and strength. There are thirty exercise load levels based on exercise frequency and desired level of workout intensity from which the exercise load can be chosen to be higher for players with greater exercise capabilities and lower for players with less capabilities. The strength required to squeeze and pull the Ring-Con controller can also be adjusted personally. Stretching before and after exercising can be determined by the amount of time used to select personally appropriate warm-ups and cool-downs. Ring Fit Adventure provides possibility to target specific areas of the body or to have an all-around workout for the whole body. There are pre-made workouts where the player can select specific areas for training with chosen intensity. Personalization allows to combine 10 exercises of choice from 43 different Fit Skills and 12 different minigames. Ring Fit Adventure uses term “Fit Skills” to define various movements and techniques that are used in the gameplay. Minigames include various movement games with simple rules for shorter periods of time. (Workouts Tailored to You | Ring Fit Adventure | Nintendo Switch | Nintendo, 2025.)

The movements in Ring Fit Adventure are monitored with the controllers together with the in-game coach that tells which movements to make while playing. The character moves according to the player so the form can be checked that it is correct while exercising. The game also provides an assist mode to avoid overstretching for example the lower back that gives possibility to switch exercises to button controls. (Workouts Tailored to You | Ring Fit Adventure | Nintendo Switch | Nintendo, 2025.)

Heart rate of the player can be measured after exercising by the controller providing feedback for the game to estimate the optimal exercise intensity for each player and upgrade or downgrade accordingly. (Sato et al., 2021.)

Outside of training adaptability the game allows modifying the character's appearance with different clothes and gear. This can also affect attack and defence ability and other stats while also just appearance can be modified with gender, skin tone and eye colour. (Workouts Tailored to You | Ring Fit Adventure | Nintendo Switch | Nintendo, 2025.)

5.2 Adaptability (Valedo Motion)

Valedo analyses the movement signals to provide accurate real-time functional feedback so that the patient knows if movements are done correctly. The system monitors the movement performance and guides through the exercises. To analyse the movements correctly Valedo requires a calibration for the sensors to calculate the Range of Motion (ROM) measurements (Valedo User Manual 2018). ROM measurement is done by mimicking the pose in the given example and it must be held briefly after which the software calculates range of motion for that specific movement as illustrated in Figure 13. With this, the application measures the limits of the user's movement, based on which they are accurately recreated on the screen. When the bar goes green the range of motion is large enough for meaningful exercise movement and playability. With red indicator user is not able to “capture” and move to the next movement. With individual ROM values the software adjusts the exercises for personal movement ability for not being too difficult or easy. (Valedo User Manual 2018.)

Each individual game in Valedo has three pre-defined difficulty levels in easy, medium and hard options which offers the patient the possibility to adjust the games based on individual performance (Alhwoaimel et al., 2024). Also, according to the Valedo User Manual (2018) there are different exercise modes available as follows:

- Precision: how precisely the movement of both sensors are controlled
- Isolated precision: how precisely the movement of one sensor is controlled while holding the other sensor still (available from level 3)
- Stabilization: how well a position is held

- Isolated stabilization: how well a position is held concentrating on one sensor while maintaining other on still (available from level 3)
- Free mode: Squats are done at own pace, not according to the timing bar as in Precision and Stabilization

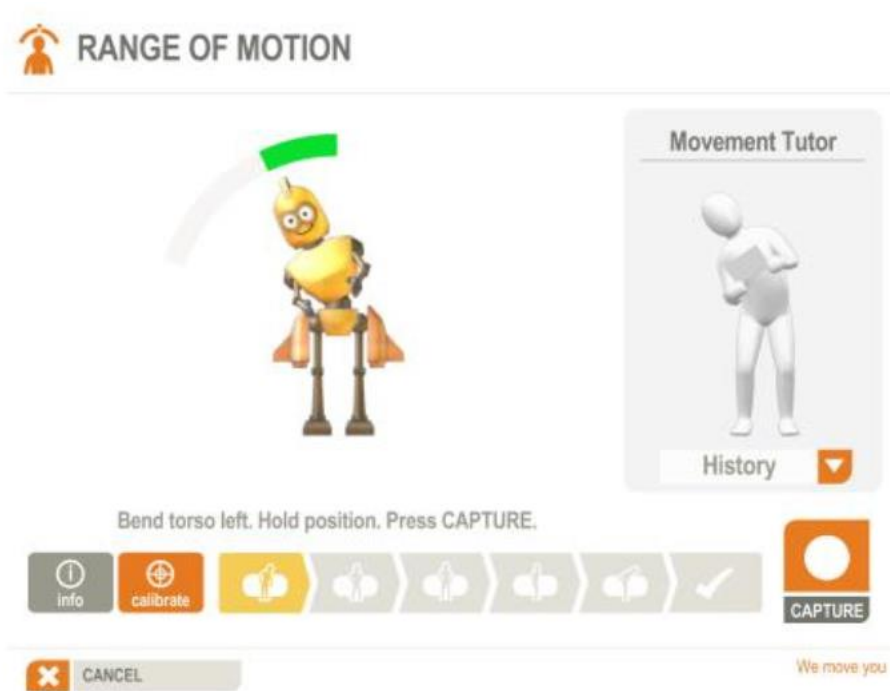


Figure 13. Range of motion calibration screen in Valedo Motion. Picture: Valedo User Manual 2018.

Valedo also offers a possibility to create and manage personal exercise plan. The patient can set an exercise schedule of own choosing with number of weeks the plan spans and with the exercises that will be used with number of repetitions and difficulty. (Valedo User Manual 2018.) Valedo doesn't seem to allow for avatar customization in terms of self-expression.

5.3 Progression

According to Adams (2014, 41) progression refers to a series of challenges that has been explicitly planned. A well-designed path towards a goal helps the player enjoy the progress they experience, especially if it includes a sense of growing power. With games the progression is often thought in terms of moving from level to level, however it can exist within a level also. (Adams 2014, 41.) In addition to levels, a sense of progression can be achieved through story, or both. If levels are used, it is possible to specify whether the player can play them in any order or whether the next level will only be available after the previous

one has been completed. (Adams 2014, 134-135.) Managing the difficulty of challenges is an important aspect when balancing a game to the point where players abilities match suitably to the problems they face. The goal is not only to set the difficulty level but to determine how to adjust so that player's enjoyment is maximized. (Adams 2014, 389.) This also supports the flow state by Csikszentmihalyi (1997) mentioned earlier (Browning 2016, 111-112).

With rehabilitation the difficulty adjustment is important in terms of personalizing the therapy for different impairment characteristics such as smoothness, compensation, precision and range of motion (Jung et al., 2020). Proffitt (2016) argues that in typical games for entertainment the difficulty between levels when progressing the game is similar to all players which in dynamic rehabilitation is not optimal. There exists a twofold dilemma in this regard, because on the one hand, therapists need the ability to adjust the level of difficulty manually, but on the other hand, automation is needed. This flexibility places significant development requirements on products.

One of the most common features in games is upgrade progression where the player gains power as the game progresses keeping the player interested and giving a feeling of accomplishment. For this the game must consider the power provided for the player when challenges are met. This means that the relative difficulty must be set in the future levels according to the level the player will be when he reaches those levels. A simplified approach is to not let player carry the earned power into the next level. (Adams 2014, 393.)

Progression is also important for motivation point of view. If there is no visible progress, it may affect motivation to continue the activity. This also provides a great way for rehabilitation to gather data and follow development in an interesting way. In addition, the difficulty level can be increased in proportion to development, thus providing a suitable challenge along the way.

5.3.1 Progression (Nintendo Ring Fit Adventure)

Role-playing similarities are present in Ring Fit Adventure with gaining experience points after every action the player partakes in. When player defeats opponents and clears course, the character obtains exercise points. These reflect the real-world exercise performance that allow levelling up in the game. With levelling up the character's abilities improve such as attack power, defence and additional points for health. Also new movements and techniques can be learned while levelling later expands into a talent tree from which various bonuses can be

unlocked such as chance for extra turn after using attack of a certain colour. Through the combination of talents and equipment the player can customize the play experience to suit their own playstyle. There is also possibility to check activity time, calories burned, and distance covered while all these reflect to the in-game character's development. (Macák 2021; Full-Body Adventuring | Ring Fit Adventure | Nintendo Switch | Nintendo, 2025.)

When player advances to a higher level it will make him stronger and make playing through the game easier. Different stages have suggestions for what level the player needs to be in order to attempt them, but it is possible to complete them even if the player is on lower level. (IGN 2020.)

5.3.2 Progression (Valedo Motion)

The progression in Valedo is visualized with developing the district of houses. The objective is to build houses and unlock new movements and districts with gems collected from completing the exercises. The size of the houses indicates the level of difficulty that has been achieved in given exercise. The more exercise is done the more houses are unlocked and the more village grows in height and appearance.

The player can achieve the next level by completing a progress challenge. The challenge can be such as “stay on the line continuously for 90 seconds” after which advancement from level 1 to 2 can be made. This is illustrated in Figure 14. As the exercise is being performed, a challenge progress bar will display on the screen. When the challenge has been completed the next level will be available. Exercises require either to follow a path or fly through rings or other different goals. At the start of each exercise there are instructions provided. (Valedo User Manual 2018.)

Player can also challenge himself with replay possibility of the levels. After unlocking new difficulty there is an opportunity to attempt replay challenges for the levels already unlocked to achieve new high score as seen in Figure 15. The previous high scores and bests in three movement categories: accuracy, smoothness and isolation are available. Accuracy rates how precise the movements were towards the exercise goal, smoothness rates how smooth the movements were and isolation rates how well one sensor was moved while keeping the other still. (Valedo User Manual 2018.)

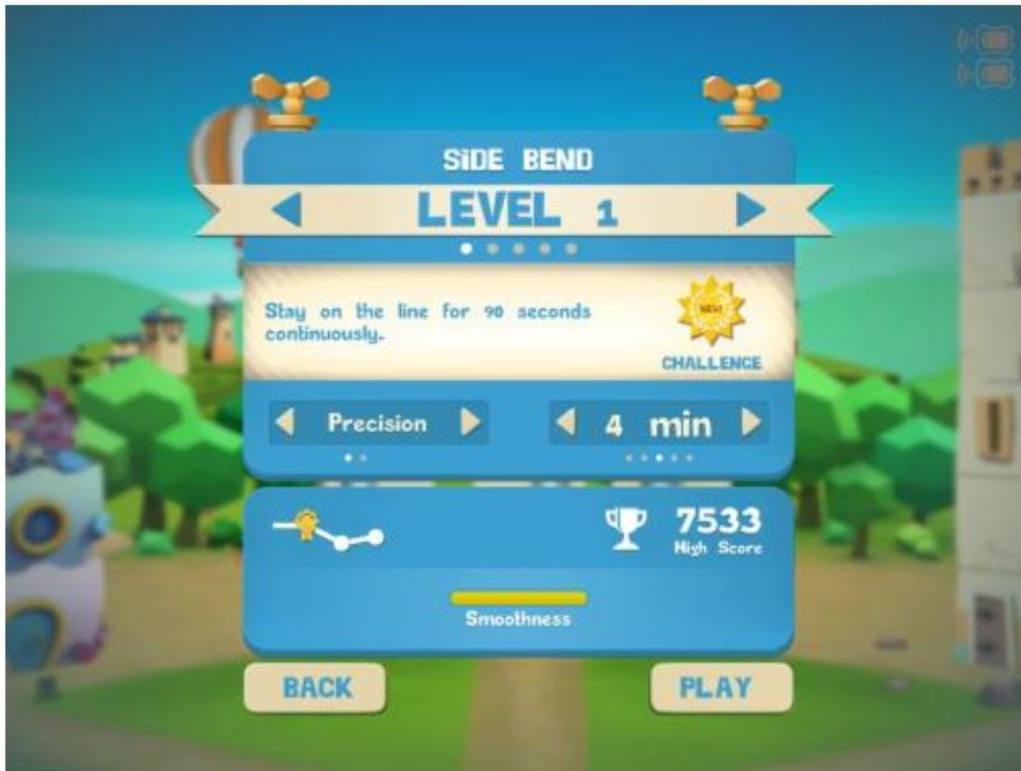


Figure 14. Training introduction in Valedo Motion. Picture: Valedo User Manual 2018.



Figure 15. Replay challenge attempt. Picture: Valedo User Manual 2018.

6 Discussion

Designing rehabilitation games is a multidisciplinary field involving game designers as well as health professionals. Health professionals usually prioritize the effectiveness of games as a form of therapy and the technology itself, while game designers are interested in considering how rehabilitation exercises can be gamified. According to researchers, due to the wide scope of the field, there is not enough interaction between the necessary communities, which can lead to inadequate solutions as not all expertise has been sufficiently utilized. A challenge in designing rehabilitation games can be the need for broad expertise to optimize the gaming experience and to maintain the effectiveness of rehabilitative treatment. This highlights the possibility that if these tools are developed with a limited number of experts, it may lead to the tools not being used in the field. (Fonseca et al., 2025.)

The research shows differences, which are most clearly noticeable in the versatility of the commercial solution with skilfully utilized entertainment features. These are to be expected in a commercial solution, but there are similarities in the use of game features. As the definition itself states, serious games are designed with a primary purpose other than entertainment, which is clear in the example serious game, as it is specifically targeted for low back rehabilitation concentrating on trunk and pelvis movements. In contrast the commercial game is designed for wide audience addressing total body physical exercise, but which also has the possibility to target the low back with certain exercises. Both solutions offer options for both the healthcare professional and the patient and can be utilized in the treatment of low back pain at different stages.

6.1 The technological solutions

There can be found similarities in the gaming devices. Nintendo Ring Fit uses Switch gaming console and although it's called a console, it is a combination of a console and portable device making it very versatile. The console can be used as tablet type gaming device or connected to a dock station through which the image can be projected to a TV. Dedicated controllers used in Ring Fit Adventure connect to the gaming console wirelessly. Valedo game can also be downloaded to a portable device such as tablet to which the sensors connect via Bluetooth. The devices and machines create a starting point and certain boundaries in terms of, for example, computing power and graphics that both games can utilize but, their portability makes both capable to be used at home, hospital or clinic environment. In a way the devices

and solutions are not far apart, but the versatility of the Nintendo Switch console shows what the experience can be at its best right now.

In the context of low back pain, the treatment usually consists of physical exercises which transfers the traditional way of gaming into more active one. This emphasizes the need for inventing and developing new ways to control the game compared to traditional game controller. In a clinical tool point of view the importance of accuracy and precision in gaming devices has a two-part dilemma (Bonnechère 2018, 134). On the one hand an accurate and very detailed analysis is needed using state-of-the-art equipment, while on the other hand, a general assessment can be done with cost-effective transportable solutions. (Bonnechère 2018, 134.) In the context of this thesis the solutions represent the latter. For controlling the game Nintendo has developed a dedicated controller in the shape of a Yoga ring which senses both pushing and pulling of the ring as well as any other motion that is being performed with the controller. Another controller detects the leg movement. Because only two sensors are used to detect full-body movements, there is a high error rate in distinguishing fitness movements (Yuan, Wei & Li 2024). Nevertheless, general assessment of full-body movements can be done.

Valedo has similar approach with two specific sensors developed and attached to chest and lower back, but without the force sensing capability. To control games, the system uses these sensors to record movements based on the relative position of the sensors while the games provide postural feedback during functional motor control exercises (Matheve et al., 2018). Valedo focuses precisely on the back movement and bending, which makes it specifically designed for low back rehabilitation. While the game control is a little more restricted, it is not a limitation, but more of a rehabilitation aspect of the game itself and its focus points. With sensor calibration the range of motion is measured for the software to adjust the exercises for individual movement ability ensuring that the exercises are not being too difficult or easy. This points out the personalized angle and approach of a serious game. Commercial games are usually criticized of not having the possibility to make individual adjustments, but Ring Fit Adventure shows that there has been put an effort to provide support for different abilities. This will be discussed later when addressing adaptability and customization.

An important aspect for controllers between these two solutions is also the feedback received through them. With Ring Fit Adventure, the player has a Ring-Con that can be pushed and

stretched, giving the player a physical input of doing something concrete. With Valedo the player doesn't receive the same kind of input when bending the torso. For the actions available with these different types of controllers sets boundaries for the gaming experience and genre. For example, when shooting an air gust in Ring Fit Adventure by pressing the Ring-Con, the same shooting is difficult to manage with Valedo's sensors. With specialized controllers it is important to both utilize and consider their characteristics. Both games have utilized the experience of the game in terms of their controllers. Patients may also have some disabilities that place demands and limitations on the handling of the controllers. What is interesting about Valedo is that because the sensors are attached to the body, the game is controlled hands-free, which is different from Ring Fit Adventure, where the hands are mainly used to squeeze the Ring-con controller. Patients with hand function challenges may benefit from a solution like Valedo.

6.2 Game design and mechanics

As Browning (2016, 116) proposed when designing serious games, it is critical to identify and start from the desired real-world outcomes for the game and progress from there adding aesthetics, dynamics and mechanics so that every decision supports the previous levels. This also reflects the player perspective that Hunicke et al. (2004) noted in their MDA framework approach. In the case of Ring Fit Adventure, the game promotes physical activity and fitness which can be thought as the outcome of the game. As a commercial game it has been targeted for wide audience which is why a more general approach to exercise is natural. In the case of Valedo the outcome is targeted specifically on the rehabilitation of low back which results into more focused audience compared to Ring Fit Adventure.

Because fun can be individual, incorporating it into rehabilitation in the form of a game is challenging. In this regard, it may be useful to consider it through aesthetic goals (Hunicke et al., 2004) in order to achieve the goal of rehabilitation while maximizing the engagement. An aesthetic difference can be seen in narrative component as the extent of storytelling in Ring Fit adventure is quite new as prior exergames have been mainly focusing on the exercise itself and story elements have not yet been incorporated as heavily as in the Ring Fit Adventure (Macák 2021). Valedo doesn't seem to have storytelling but the minigames are tied to a house district that the player can develop with collected gems while unlocking new movements and districts providing a storyline type of continuation, although not as comprehensive as what Ring fit Adventure offers. The deeper storyline remains hidden as there are no reviews of the

gameplay available. The narrative component can offer the patient a way to motivate and learn and get deeper understanding of the rehabilitation while for the healthcare provider it can offer the possibility to teach, train and educate the patient in form of a story. Similarity can be seen in aesthetic goal of discovery as new exercises and levels are unlocked when advancing the game although Ring Fit Adventure makes the use of this more extensively. Also Ring Fit Adventure provides more character customization which Valedo doesn't seem to have at all.

Aesthetics should not be neglected as it can maximize the engagement through enjoyability which is emphasized in commercial games as Browning (2016, 117) stated. Ring Fit Adventure is a good example of this. The outcomes of the rehabilitation can be enriched through different aesthetic goals to provide fun in its various forms while also being rewarding. Aesthetically Valedo doesn't fall far when compared to Ring Fit Adventure which might also point out that the interest in development of serious games has grown over the years. When discussing aesthetics in the form of graphics the devices and computing power sets certain limits which was discussed earlier, but with today's technology this doesn't seem to be major issue. Artistic freedom can also be utilized by making more cartoon-like games instead of aiming for as authentic graphics as possible.

The dynamics in both games are utilized with the physical engagement that provides the movement of the in-game avatar while in Ring Fit Adventure the amount of different exercise moves is wider compared to Valedo. This is somewhat influenced by the audience and target for which the games are aimed. Ring Fit Adventure's turn-based combat system shows a smart way of combining physical movement with role playing game elements. It introduces a strategy element in the gameplay that is matching exercises to defeat the enemy. It shows that these elements are not just added into the game, but they have a specific reason that may also help with strengthening the intrinsic motivation. To defeat the enemy more easily you need to learn new skills which in turn makes the player's exercises be more versatile and through this be more effective in terms of exercise itself. (Macák 2021.) With Valedo the number of physical movements is more limited, which poses challenges to the imagination when thinking about how to move the player and how these movements can be utilized in gameplay.

The mechanics as in input method differ as in Ring Fit Adventure the ring-shaped controller can be squeezed, stretched, pointed down or held up which brings wide variety in the range of

actions that can be performed. In battle scene, resistance training and yoga exercises are used to defeating the enemy and clearing the level. In Valedo the game is controlled with dedicated sensors attached to the back. In different minigames player collects collectables and avoids objects, tries to fly up and down through hoops, controls platform to move a ball and directs different items between two baskets. All this is done by controlling trunk or pelvic by tilting to different directions. The performed actions are somewhat more limited compared to Nintendo's vast number of exercises but are reasonable when considering the way the player is moved, a more rehabilitation-oriented approach is conveyed. Valedo concentrates more for the precision, isolation and stabilization of movements which is more focused on the rehabilitation goals and providing a visual connection to the range of the movement. There doesn't seem to be the same level of strategic perspective to the gameplay as in Nintendo's case, but engagement and interactivity have been brought in the form of collecting gems to build houses and unlock new movements.

6.3 The engagement methods

Multimodal feedback mechanisms exist in both games in regards of rehabilitation and gameplay. Feedback needs to be informative and helpful that drives to improve the performance. One of the important feedback mechanisms in the context of rehabilitation are visual cues of performing the exercises correctly. The clearest feedback is received through the avatar in the game that reacts to the players movements. The interaction model that both games utilize is avatar-based character from a third person view moving on a fixed path. Citing other researchers Morone et al. (2024) pointed out that in terms of rehabilitation first-person view allows effectively eliciting a sense of body ownership whereas third-person view activates a mirror neuron system which is essential for successful sensorimotor rehabilitation. Both games can transmit the result of the interaction to the patient. The movements in Ring Fit Adventure are monitored together with the in-game coach that tells which movements to make while playing. The character moves according to the player so the form can be checked that it is correct while exercising. Similarly, in Valedo the robot flies according to the bending of torso while other games are also controlled by hip movement. With Valedo the range of motion acts as boundaries for the movements, while Ring Fit Adventure informs if for example Yoga pose is not stretched far enough or squats are not done low enough (Dornbush 2019). This is beneficial for the patient, but also for the caregiver as they both can trust that the system will guide through the correct exercises highlighting the usefulness of the system. In addition to visual cues, both games provide also audio cues as feedback.

Interesting perspective of providing positive feedback in Ring Fit Adventure is defeating enemies with exercise that is done using players own strength (Macák 2021). The same is experienced with Valedo as posture feedback helps patients perform exercises more correctly and feel more confident while doing them, but also making them more motivating and fun compared to traditional training. (Matheve et al., 2018.) Valedo also demonstrated that training with sensor-provided data on graphical displays resulted in superior performance compared to training without feedback or training in front of a mirror (Meinke et al., 2021). On the other hand, Valedo has a scoring system, where a mistake results the player losing significant number of points making it frustrating as all the earned points are wiped away (Alhwoaimel et al., 2024). When playing a game players like to feel successful, and the in-game feedback should reward the effort and engagement instead of promoting only perfect performance (Ushaw et al., 2015). Losing most of the points may be too big a penalty considering that the game is about mobility where player levels can vary considerably.

Regarding feedback in the form of gamification mechanisms, there were in total 29 gamification elements presented in Table 1. Ring Fit Adventure includes total of 24 elements while Valedo includes total of 16 elements. The ones that are missing from Valedo are: brag button, collection set, crowning, leaderboard, prize pacing and social feedback. In overall the social elements seem to be more present in Ring Fit Adventure, which could be explained by the fact that it is developed for a commercial market, where part of the game's appeal is that users share their achievements with other users. Socialization may expose to competition and according to Browning (2016, 107-108) serious games should avoid competitive rewards to avoid interfering with intrinsic motivations. Rewards should provide players with feedback on their performance rather than task engagement (Browning 2016, 108). Prize pacing could favour just the task at hand so the absence could be justified. Crowning on the other hand can provide feedback in success, but the true absence cannot be confirmed. Although the presence of gamification elements is not in itself a measure of a successful game, Valedo has utilized gamification elements surprisingly extensively when comparing to Ring Fit Adventure. Important to keep in mind is that these are encouraging, positive and rewarding. Not everything needs to be gamified, and it can also have negative effects if used incorrectly (Browning 2016, 106-107). An example of this could be the Valedo points system.

6.4 Customization

Rehabilitation is usually a dynamic intervention that requires the game to be customizable and allow different exercises based on the needs of the patient (Adeel et al., 2022). Commercial games serve general population which can raise challenges rehabilitation wise because the starting points of the patients can vary very significantly. However, it is notable that Ring Fit Adventure does provide wide variety of customization in terms of training difficulty and load. In additions to modifying the training levels the physical controllers can be modified with sensitivity of the strength needed to operate the Ring-Con controller. Also, while the game provides workout for the whole body there is possibility to target specific areas of the body like the low back area. The range of motion can also be compensated with assist mode where exercises can be switched to button controls avoiding overstretching. Jung et al. (2020) discussed that commercial games are usually designed for non-disabled people and what is noticeable in Ring Fit Adventure is that it does provide somewhat compensation to disabilities. Certain muscle groups or body parts can be toggled off which affects the gameplay (Dale 2019). For example, with knee assistance mode as big part of the adventure mode is jogging through the levels, this aspect is automated, and the player character will move automatically through the environments allowing for seated play. The other assistant modes include shoulder, back and abb assist. (Dale 2019.) Outside of training adaptability Ring Fit Adventure offers also customization options for the appearance that serves as a personalization of the interaction.

Valedo's customization focuses on the range of motion of the trunk and hip. The software uses this information to adapt the extent of movement required for every individual user. Because the number of movements is more limited due to the game's clearer focus on lumbar movements, there is no similar need to exclude various movements as in Ring Fit Adventure, which loads the entire body. In addition to the adjustable difficulty level Valedo's exercise modes provide customization for the training from the point of view of precision and isolation.

Both games show how customization and adaptability towards physical movement can be supported with digital games. While commercial games have been criticized of not considering the variety of what rehabilitation patients require, Ring Fit Adventure shows how even though the game is designed for commercial market there has been put effort to

compensate also players with disabilities or concerns towards specific muscle groups or body areas.

As rehabilitation is usually a journey towards restoring a previous capability, both games have functionality that increases the difficulty level as the player's experience increases. In Ring Fit Adventure, this is shown as training points for the player avatar for each action the player takes part in. From time to time, enemies appear to be fought against. Accordingly, as the player gains experience, the resistance of the enemies also increases. This shows how positive feedback can be received after successful combats. When player obtains more power, continuing to offer the player meaningful challenges can be done by increasing the strength and numbers of the enemy. The cycle continues with defeating stronger enemies from which the player receives larger rewards. (Adams 2014, 402.)

With Valedo the progression is visualized with size of the houses per given exercise while the level of difficulty emerges through muscle stiffness and from the movements performed either by sitting or standing. Valedo seems to use mainly high score system where player competes with himself. As both games require body movements to control the games the physical capability needs to be considered which was done in both games. Ring Fit Adventure has a possibility for an assist mode to avoid overstretching and switch exercises to button controls while Valedo offers the measuring of Range of Motion that can be re-evaluated as often as needed providing sufficient resistance relative to one's own level. While in Ring Fit Adventure's case the assistant mode might provide way to progress further it can be debatable is it suitable for rehabilitation purposes. On the other hand, it points out that Ring Fit Adventure is a commercial game that serves general population.

7 Conclusion

In the scope of rehabilitation commercial games have often been preferred for their more engaging and entertaining experience when compared to serious games even though serious games may offer better clinical outcomes. On the other hand, commercial games have usually been criticized of neglecting people with disabilities and focusing only on healthy people.

Ring Fit Adventure demonstrates a result where a game company and health professionals collaborate. The playing experience is what from a commercial title can be expected while the exercises have been thoughtfully integrated to provide the goal of a full body training or a specifically targeted area. Valedo demonstrates what the serious games can achieve so far. Aesthetically, the mini games look reasonably good. The gameplay utilizes specifically the back movements making it more limited but more precisely focused on specific motion paths in accordance with the goals of low back rehabilitation. This in turn highlights how from simple movements the collaboration of health experts and game developers has produced a decent playing experience

When it comes to technology in rehabilitation context, portability is an asset. Most of the time, the patient must be able to use the solution at home, where rehabilitation is often done. In the example games in this thesis, both meet this characteristic as small tablet-based games where the controllers are also of a reasonable size, and there are no large units. This also sets requirements for the quality of the game in terms of computing power which is not necessarily a problem as today even small devices can handle gaming graphics effectively. Also, with cloud gaming the data could be computed on a remote server reducing power requirements for local devices.

Rehabilitation utilizes movements that are typically performed with either a part of the body or the whole body, so games need to take this into account. This creates new demands on how games interact with the user and the game. Ring Fit Adventure is a good example of how full-body training has been utilized in the game world, while Valedo uses sensors to target and transfer movements back to the game world for control. Part of the challenge is that rehabilitation is unique to each individual and the exercises used can vary greatly as well as the capability of the patients. Making a game that covers all scenarios can be very challenging, if not impossible. Furthermore, the problem with games is not necessarily that they do not have rehabilitation-supporting features. Example games have shown that it is

possible to adapt games to individual needs in both commercial and serious games. It is important to utilize multidisciplinary expertise when making rehabilitation games, such as the skills of doctors, physiotherapists and game developers, so that the full power of games can be utilized in supporting rehabilitation.

A challenge raised in studies is the decline in motivation over time, also in games.

Rehabilitation usually is a long process, and there are not yet enough long-term studies to show results in this regard. A game that keeps you motivated for the foreseeable future is a challenging task, although some games have kept players interested for years. However, one could ask whether a game even needs to last forever. Different games can be used at different stages, for example, the serious game mentioned in the thesis would be suitable for the initial stage, where mobility may be very limited due to pain. As the situation improves, more comprehensive activities can be introduced, which is again supported by Ring Fit Adventure. The care givers expertise is needed when planning a rehabilitation journey, games are tools to utilize. Another challenge is that patients with the same diseases may not receive the same treatment due to underlying factors. Therefore, the use of serious games in treatment is not so simple, as it must consider not only the goals of treatment but also the abilities of the patients. It may be necessary to develop several serious games to consider different factors for the same disease, while commercial games can focus on providing entertainment to a wider audience. In the future, the customizability and adaptability of games can be expected to develop with machine learning and cloud services. These can offer both more personal adaptability and wider entities within a single game without placing too high demands on the local device.

Rehabilitation clients are also a diverse group in terms of age, which means that their technological background varies. Younger generations are more accustomed to gaming than older generations, and not everyone enjoys playing games. This also poses challenges for game development, as traditional user interface designs used in games are not familiar to everyone, and in addition, the speed of games should be considered to ensure their suitability for different user groups. Not everything can be gamified, and it should not be an end to itself, but rather to support intrinsic motivation.

When developing games commercial ones usually have wider audiences making them more attractive to develop compared to a more limited audience that rehabilitation represents. However, today's different application stores allow smaller creators to distribute games,

offering the opportunity to reach a targeted audience. But still, it presents a problem with how to earn with serious games. The opportunity is smaller for developers compared to commercial games, which in turn affects the competition and development of games designed for rehabilitation purposes.

One of the challenges in this study was the lack of research papers dealing with the gamification or game mechanics part of serious games. While information is widely available in commercial game reviews, for serious games these doesn't seem to exist. Serious games are usually evaluated from the perspective of rehabilitation success. There does not seem to be an assessment of game characteristics or gameplay, which would certainly benefit the future development of serious games. Also, it appeared that the Valedo Motion was no longer available through official channels. Lack of recent information and announcements regarding the product was missing and no information could be found regarding Valedo Motion in Hocoma's home page. This is interesting as the solution has been used and studied in several cases pointing out the usefulness of the solution regarding physical therapy of the low back.

Rehabilitation has many starting points and goals, and each rehabilitation is different and is built according to the individual. This is why a solution that serves all scenarios is difficult, if not impossible, to implement. On the other hand, one can ask whether it is even necessary to try to invent such a thing. Rehabilitation is the responsibility of care givers who build the rehabilitation journey according to the patient's needs. It is good to have different tools that can be used as needed. For this reason, when considering rehabilitation games, each solution has unique strengths. Serious games offer targeted benefits, while commercial games offer versatility and engagement. Both solutions can learn from each other, and by combining these, it is possible to develop even better solutions in the future.

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Appendices

Appendix 1 Gamification elements

Table 2. Gamification elements and definitions.

A premade list by Sienel et al. (2021) with definitions for each gamification element as collected by Vieira et al. (2022).

Element	Definition
Achievement Symbol	Can also be known as “badges” (although they can come in many forms). They symbolize achievement but are not achievements by themselves. They are given to the user once they accomplish a certain intended task, therefore working towards making the user feel accomplished (Chou 2016).
Assessment	Refers to the act of measuring for a finite period (Swacha & Muszynska, 2016).
Avatar	Avatars are often customizable and contribute towards a sense of ownership which consequently works towards enhancing motivation by providing a representation of the player (Chou 2016).
Brag Button	A way for the user to “brag” about their accomplishments. A good example of this would be adding the possibility to share a screenshot of the user’s high scores in a certain game to social media (Chou 2016).
Challenge	Can be described as one of the most popular elements of gamification (Arango-López et al., 2017). Works towards making things meaningful: a trophy or badge without challenge is not perceived as something meaningful (Chou 2016).
Choice	People tend to like something more when they are given a choice than whether they are offered a single option, therefore the importance of the presence of the choice element as part of gamification (Chou 2016).
Collection Set	If there’s something that’s part of a set, it will awaken the desire within users to collect the remaining items/badges/achievements to fully complete the set (Chou 2016).
Crowning	A gamification technique for development and accomplishment (Swacha & Muszynska 2016).
Difficulty Selection	A technique that allows the user to select a level of difficulty before they engage with the gaming experience (Ferro 2018).
Discussion-board	A tool to promote discussion among players (Hallifax et al., 2019).

Element	Definition
Feedback	A way of allowing players to know how they are performing and to adjust their performance in turn (Chou 2016).
Gift	Items or rewards that can only be given to the users by other players (Chou 2016).
Leaderboard	Game element that works towards ranking users based on a set of criteria that is influenced by the users' behaviours towards the desired actions (Chou 2016). Generally based on parameters such as points (Ferro 2018).
Level	The current "status" of the characters/avatar/user in the game that grants them certain stats and abilities (Chou 2016). It is also, a way of providing a sense of progress to a player (Ferro 2018).
Number Limit	A limit of things a player can do: maximum level, total number of things a player can collect, and so on (Chou 2016).
Performance Graph	A visual graphic that shows the user how they performed at a certain task (Chou 2016).
Permadeath	Permanent experience of the user as a player character. If a user wants to continue, they must start over from the beginning (Ferro 2018).
Points	Something a user earns over time as they perform the desired tasks, according to their performance. Usually a numerical value (Chou 2016).
Prize Pacing	A way to encourage users to proceed with the ongoing tasks until full completion (Swacha & Muszynska 2016).
Progress Bar	Shows the user their progress towards achieving something and influences their behaviour (Chou 2016). Can be described as a form of feedback that the application shows to the user in real time and allows them to see their advances constantly (Arango-López et al., 2017).
Record	A way to let the player know that they can complete the given task much better or much faster and attribute a reward upon setting a new personal record (Swacha & Muszynska 2016).
Reward	Something of value within the context of the game/an item users get when they commit the desired actions and arrive at the win state (Chou 2016).
Schedule	Determines the calendar the player/user must follow to complete the assigned tasks to get a reward (Hallifax et al., 2019).
Social Feedback	A way of providing an evaluation of behaviour (Finkelstein & Fishbach 2012)

Element	Definition
Social Graph	Gamification technique related to social influence and relatedness (Swacha & Muszynska 2016).
Team	Refers to a group of people that work together to achieve a certain end (Chou 2016). As a gamification technique, team provides a means of social interaction (Hallifax et al., 2019).
Time Limit	A way of limiting how long it takes a player to complete a certain objective: it usually triggers the sense that if a player does not act immediately, they will fail or lose the opportunity to act (Chou 2016; Ferro 2018)
Torture Break	Sudden and often triggered pause to the desired actions. It often comes with a relative timestamp based on when the break is triggered (e.g.: return 5 hours from now) (Chou 2016).
Unlocking	Works towards opening a new possibility that was not there before a certain milestone is reached (Chou 2016). This often requires the completion of prerequisite objectives (Ferro 2018).