

# Serious games and rehabilitation: a literature review

IMT4307-Serious Games Course report

1<sup>st</sup> Benjamin Normann Skinstad

*Department of Computer Science of NTNU*

*Norwegian University of Science and Technology (NTNU)*

Gjøvik, Norway

benjamns@stud.ntnu.no

**Abstract**—With an increasing population needing assisted living and rehabilitation due to various disabilities, the healthcare system will have difficulties dealing with the increased number of patients, and providing them with personalized care will be complex. With the technological progress of serious games, it has become possible to create rehabilitation games aimed at disabled individuals.

This paper aims to research the current state of rehabilitation focused serious games and their effectiveness, with the paper focusing primarily on the possibility of developing a system for the general rehabilitation of disabled individuals.

The results indicate that it is currently challenging to create systems for a generalized group of disabled individuals, indicating that developing a shared rehabilitation platform would be challenging.

The results also indicate that using serious games in the rehabilitation of various disabilities is highly effective, with most of the results indicating a positive effect of its usage.

**Index Terms**—serious games, rehabilitation, physical disabilities

## I. INTRODUCTION

It is currently estimated that a billion individuals will soon require assistance with everyday living due to various disabilities [1]. With such a strain on the current healthcare system, alternative rehabilitation methods need to be researched and developed. It is highly likely not possible to provide personalized healthcare rehabilitation possibilities using a professional rehabilitation worker for every individual whenever said individual required it. This is both due to an issue of price and availability. Many rehabilitation exercises require the patient to perform them by oneself between appointments for improved effect. It is reported that the main reason for exercise drop-out is due to the lack of motivation among patients [2].

Disabled and marginalized groups are traditionally not taken into account when designing games or game-related hardware. This makes it, so they have little access to game-related entertainment and struggle with partaking in normal serious game-related activities.

In this paper, I will perform a systematic literature review and research how game technology is used in rehabilitation. This paper will first and foremost review hardware technology through the lens of serious games and extend itself to include software technology if deemed relevant.

## II. SCOPE

The focal point of this paper will be looking into research papers that focus on using game technology for rehabilitation and exercise purposes in disabled individuals. I will mainly look at hardware-related papers, but I will, if deemed relevant, review software specific papers. I will look into papers covering physical and mentally disabled individuals, the elderly, and other marginalized groups. This paper will also try to research if there has been a change in trends in research over the years. I aim to document what the current state of this field is, and I will try to link the various research to find out what could be done to streamline and improve this field.

## III. STRUCTURE

The paper will follow this structure:

- Ch. 1: Introduction
- Ch. 2: Scope
- Ch. 3: Structure
- Ch. 4: Motivation
- Ch. 5: Related works
- Ch. 6: Methodology
- Ch. 7: Results
- Ch. 8: Discussion
- Ch. 9: Flaws
- Ch. 10: Conclusion
- Ch. 11: Future work

## IV. MOTIVATION

After selecting the "Technology" topic area, I conducted an initial search through various serious games journals looking for papers that focused on technology. I combed through the journals looking for various papers that discussed technology in their abstract. I mainly focused on hardware discussion over software technology, but I saved them all for later research. My original idea was to research the current state of VR technology and improve the effects of serious games for players, but I discovered a theme when I looked through the various papers I had saved. A large portion of the technology papers I had saved focused on utilizing technology to widen the reach of serious games, mainly focusing on marginalized groups and people with various disabilities. I also saw that these papers overlapped with research papers focusing on

serious games and rehabilitation. Discovering this, I wanted to do a deeper look into research that has been conducted by researchers on how to effectively use technology to reach these groups that generally are unable to play serious games in the designed way.

My main question was: why is there no shared standardized platform or design pattern that aims at making serious games available for marginalized groups or the disabled. Most of the papers I read created their platform or heavily customized existing hardware or software to focus their system on a specific group of disabled individuals, questioning why there are no shared serious games rehabilitation platforms that aim at disabled individuals in general.

## V. RELATED WORKS

My related work section is a bit short because most of my research is located in the result section. Several studies have been performed over the last 20+ years in terms of serious games-based rehabilitation research. Very few of these studies have been on the general application of serious games and rehabilitation, but some notable examples are:

*Virtual, Augmented Reality and Serious Games for Healthcare I [3]*

While discovered late in my research, this book extensively covered much of the field I wanted to look into. It was well structured and contained many concrete applied examples of serious games based rehabilitation and its effect.

*Exergaming for individuals with neurological disability: a systematic review [4]*

This paper conducted an extensive review of the effectiveness of exergames for individuals with a specific condition to conclude its effectiveness. The paper's methodology and review strategy was inspiring, and their results support my research question.

## VI. METHODOLOGY

As mentioned in the motivation section, the initial search started with looking for papers related to technology and gamification. I started looking through all published papers by the journals: games.jmir.org, eudl.EU/journal/sg and www.hindawi.com. All papers that referenced technology and serious games were noted down. After reading over all the papers, I noticed the pattern above using technologies and challenging games in rehabilitation. The papers noted down from the three journals were reviewed again, noting down all papers discussing rehabilitation, marginalized groups, and methods to provide personalized experiences for specific groups.

Using the papers I noted down from the journals, I performed an extensive search using Google Scholar and connectedpapers.com. The terms I used in Google Scholar were: "technology games physical problems", "handicapped technology games", "exergames handicapped", "exergames wheelchair", "serious games exergames", "serious games exergames technology", "serious games exergames [technology]

". These terms were created based on trends observed in papers found in the journals above. I prioritized papers in English, published after the year 2000, and focused on rehabilitation and the usage of physical objects to assist in the process.

With the list of papers, I used connected papers on a few articles I had found to be very fitting for the topic at hand, resulting in more papers that I deemed fitting to be noted down.

During casual research on rehabilitation and exergames, I found a few papers that were also noted down. The result was a list of 60 papers and three books. Whereas 36 of these were kept due to their relevancy, and 24 were removed for various reasons. All papers can be found in the spreadsheet in the appendix, with the removal reason specified for each paper.

## VII. RESULTS

This section will go through the papers I deemed relevant and highlight their key contribution to this field. I want to note that some of these papers are not directly relevant to the field of rehabilitation, but they contain information I used to shape the discussion section and my conclusion. Some papers have similar key findings, but they are still highlighted below to showcase consensus between the findings of various researchers.

*Exoskeletons With Virtual Reality, Augmented reality, and Gamification for Stroke Patients' Rehabilitation: Systematic Review [5]*

This paper used a serious game to test out rehabilitation techniques using VR/AR and Robot-assisted therapy. The paper is mainly a literature review, going through published papers in various journals and documenting the findings. Their findings indicate that games can be used to improve a users experience, and gamified elements make it easier for users to understand complex technology about rehabilitation tools—the paper documents how VR can improve rehabilitation, especially by being a more motivating method for users. The paper notes that it is unsure how effective VR rehabilitation is compared to traditional rehabilitation methods. The paper cannot provide accurate AR-related rehabilitation methods because it was an emerging field when this paper was published.

The paper concluded that serious game focussed rehabilitation lacks proper research, especially in terms of broadness.

*Feasibility of a Commercially Available Virtual Reality System to Achieve Exercise Guidelines in Youth With Spina Bifida: Mixed Methods Case Study [6]*

This paper researched how VR can be used to increase motivation in children who use wheelchairs focusing on exercise. The study is very short and used a small sample size, but it concluded that they saw an increase in motivation for exercise in their participants. The paper discusses how specialized technology is currently becoming more available for healthcare professionals, opening new areas in terms of rehabilitation.

*Use of a Smartphone App to Increase Physical Activity Levels in Insufficiently Active Adults: Feasibility Sequential Multiple Assignment Randomized Trial (SMART) [7]*

This paper tests how smartphone applications can be used to make adults more active and increase their motivation. The paper highlights problems with new technology and how technology needs to be personalized for the best results among users.

*Perception of Game-Based Rehabilitation in Upper Limb Prosthetic Training: Survey of Users and Researchers [8]*

This paper focused on using game technology concerning rehabilitation in a specific group of disabled individuals. It highlights new ways of thinking about technology and its use cases. It also highlights the importance of cooperation between hardware and software and how they must be tailored to specific user groups. The paper also documents the design challenges in designing technology for the elderly or groups normally unfamiliar with emerging technologies.

*Virtual Reality-Based Executive Function Rehabilitation System for Children With Traumatic Brain Injury: Design and Usability Study [9]*

The paper documents the research and development of software for specific hardware with serious games in mind. The paper goes very in-depth on hardware-related technologies and highlights how systems need to be designed regarding interfaces. The paper also documents hardware limitations. The paper is designed to be a tutorial or a pilot study for future research in the field.

*Pedestrian Inattention Blindness While Playing Pokémon Go as an Emerging Health-Risk Behavior: Case Report [10]*

This paper documents problem with emerging technology fields and how technological progress can happen such rapidly laws and regulations are left lagging. It also brings up the dilemma of system design issues versus human issues regarding how systems are being used. The paper also documents how technology, focusing on mobile phone games, has been used to improve the physical shape of users.

*Adapting the Wii Fit Balance Board to Enable Active Video Game Play by Wheelchair Users: User-Centered Design and Usability Evaluation [11]*

The paper documents how off the shelf hardware might not be constructed with special needs individuals in mind, focusing on usability problems with the Wii system. The paper documents how off the shelf hardware can be customized to fit special needs individuals, focusing on making games accessible for wheelchair individuals. The paper focuses on the resources, experience and skills required to perform this customization task. The paper concluded with a set of design principles that should be considered when designing serious games with accessibility in mind.

*The Task Walking Straight as an Interactive Serious Game for Blind Children [12]*

This paper highlights non-clear use cases of existing technology. It highlights how groups normally are ignored in game design, and entertainment can be reached using custom technology. The paper states that technology can be used to improve "sensory efficiency, recreation and leisure, and education in the use of technology".

*Playable One-Switch Video Games for Children with Severe Motor Disabilities Based on GNomon [13]*

This paper focuses on creating technology to make games available for children who are normally not able to play games. The paper highlights how technology can bridge the gap between children with disabilities and non-disabled peers. The paper concludes that creating such hardware and software is difficult, highlighting many design-related challenges, but their results look promising.

*An Open Platform for Full Body Interactive Sonification Exergames [14]*

The paper discusses interesting features hardware and software can provide serious games designers. It highlights data available via body sensors, making it so games now have more data to work with in terms of customization and personalization of user experiences. The paper documents how recent trends in off-the-shelf technology have made these traditionally expensive sensors cheaper and available for the average consumer. The paper concludes by highlighting the lack of standardization for hardware and software when targeting marginalized groups.

*Wearable Sensor Networks for Motion Capture [15]*

This paper documents how various hardware systems can be mixed to create a consistent user experience, providing designers access to new data. The key highlights of this paper are how it documents how software needs to be designed around hardware.

*Exergaming for individuals with neurological disability: a systematic review [4]*

This paper performed a systematic literature review of papers relevant to neurological disability and rehabilitation using exergames. The paper highlights how technology and game elements can be used to increase exercise motivation among participants. The results of this review indicate that the usage of exergames has the "potential to provide moderate intensity physical activity as recommended by ACSM™ or WHO in populations with neurological disabilities". However, as the paper also states, that more research is needed before a concrete conclusion can be drawn, focusing on the lack of longitudinal studies in this field.

*A Gesture Recognition Approach for Wheelchair Users in an Exergame [16]*

The paper documents the research and development of an exergame game created for wheelchair users focusing on gesture recognition of wheelchair users. The results indicate that gesture recognition systems can be used with success among wheelchair users, especially since the system is designed around familiar gestures familiar to the users. The paper builds custom software that uses off the shelf hardware systems to make more interactive games for wheelchair users. The paper highlights how software needs to be designed around the hardware available.

*Exergame Rehabilitation System for Severe Cerebral Palsy [4]*

This paper documents how exergames can be designed and used in rehabilitation in children with severe cerebral palsy. The paper highlights how the system they use, MIRA, has been tested on various user groups but lacks clinical testing. The paper references how various groups have special needs that must be addressed during rehabilitation, indicating a need for personalization possibilities in the systems. Quote from the paper: "Software needs appropriate adaptation to children, and customized to the point where able-bodied children, and those without learning difficulties can play fairly with a handicapped system (similar to golf), The drive to mainstream inclusion of children with neurodisability means greater adaptation is needed for future specialized intervention and rehabilitation."

*Effects of Commercial Exergames on Motivation in Brain Injury Therapy [17]*

This paper focuses on the effect off the shelf hardware has on exergames aimed at individuals with brain injury therapy motivation level—the paper documents how exergames can increase motivation among users to perform repetitive exercises required for rehabilitation. The results of this paper indicate that the usage of exergames in the rehabilitation of this group works poorly, with the paper stating that more research in this field is required.

*Astrojumper: Designing virtual reality exergame to motivate children with autism to exercise [18]*

This paper looks into methods to make mentally disabled individuals more inclined to perform the exercise. The paper states that individuals with mental disabilities usually have a sedentary lifestyle. The paper conducts the research and development of a game aimed at motivating said children, indicating that exergames can be used to motivate the children to exercise. The paper questions the validity of the results and states that more research needs to be performed.

*Augmented reality-based assistive technology for handicapped children [19]*

The paper documents ways AR can be used to assist in the learning of disabled children. It documents how specialists can easily use different methods of learning based on the child and how new technology can open new areas of education.

The results of this paper show great potential. The paper also states that there has been an increase in monetary funding of these systems by larger companies.

*FlyingBuddy2: A Brain-controlled Assistant For the Handicapped [20]*

The paper documents future possibilities regarding new human interface possibilities and provides disabled individuals with new possibilities. This paper is more designed as a thought experiment than a proper research paper.

*Usage of VR Headsets for Rehabilitation Exergames [21]*

This paper performs a large scale investigation on the effect of exergames. The paper wants to look into methods to level the playing field between disabled and healthy gaming capabilities. It researches methods to boost disabled individuals during game sessions to increase their motivation. The paper wants to investigate the effect of VR based rehabilitation, but the paper concludes with indecisive results. The paper highlights the differences between normal screens and VR headsets, indicating that there might be unresolved conflicts in design that require further research.

*Designing a Platform for Child Rehabilitation Exergames Based on Interactive Sonification of Motor Behavior [22]*

This paper documents the many factors and stakeholders that need to be considered when designing systems for disabled individuals, "including clinicians, therapists, engineers, human factors experts, parents, and children themselves." The paper states that a recent trend is focusing on the development of serious games for disabled individuals. The project covered by this paper uses many different forms of hardware and software in the research and development of their system, highlighting the resources needed to develop these kinds of games. The paper concludes that the results of the experiments show promise but require more research.

*User-Centered Design of Serious Games for Older Adults Following 3 Years of Experience With Exergames for Seniors: A Study Design [23]*

This paper conducts a long term study on the effect of exergames in elderly individuals. The paper highlights many factors that need to be considered when designing systems for the elderly, like the need for trust from the users, multiple forms of disabilities that need to be taken into account, users input should be taken into account throughout the design process.

The paper lacks quantifiable results but provides a set of best practice guidelines for developing exergames for the elderly.

*Serious games for arm rehabilitation of persons with multiple sclerosis. A randomized controlled pilot study [24]*

The paper documents the usage of off the shelf Wii and Kinect systems to create a serious games platform aimed at arm rehabilitation in a specific group of individuals. The paper documents an increase in the physical abilities of the individuals, but the paper questions the motivational increase of participants.

*Serious Games Based on Kinect and Leap Motion Controller for Upper Limbs Physical Rehabilitation [25]*

This paper documents the research and development of a rehabilitation exergame; it highlights the practical aspect of development and the high costs of developing these systems. The creation of these systems and the operation of them require much money, time and skills. The paper indicates that the high cost of developing these systems might not be worth it compared to traditional rehabilitation.

*Serious games for health — Proceedings of the 18th ACM international conference on Multimedia [26]*

The paper claims that sports and traditional exercise are better than exergames using computer systems. The paper highlights the difficulty of creating systems that individuals unfamiliar with a technology need to operate. The paper states that multiplayer games are greater motivators for long-term repetitive tasks than individual therapy and highlight accessibility problems with multiplayer rehabilitation games.

*Game Design for Users with Constraint — The 31st Annual ACM Symposium on User Interface [27]*

This paper details how users need to be taken into account during every design and development process.

*Future Trends in Exergaming using MS Kinect for Medical Rehabilitation [1]*

This paper documents the usage of off the shelf hardware for rehabilitation purposes. It goes into how over a billion individuals will require care for normal living, highlighting the need for other methods than traditional rehabilitation practises. The paper states that there has been an increasing trend in the technology fields regarding rehabilitation and the development of exergames. The paper states that exergames themselves can not be used as the sole source of rehabilitation but should complement traditional rehabilitation exercises. Like the paper "Serious games for health — Proceedings of the 18th ACM international conference on Multimedia" also stated, this paper highlights the need for interfaces aimed at individuals who are computer illiterate. The paper highlights many forms of disabilities out there, who all need special design needs in any system they will operate. The paper concludes that exergames are excellent at teaching individuals rehabilitation techniques due to games built-in feedback systems and other visual aids.

*Digitizing the Hand Rehabilitation Using Serious Games Methodology with User-Centered Design Approach [28]*

This paper documents the various stakeholders that need to be taken into account when developing rehabilitation systems, not just the patients. The paper highlights the effectiveness of using off the shelf systems in rehabilitation but also highlights the limitations of off the shelf hardware gives designers. The paper concluded that "the patients reported a high level of enjoyment and motivation while playing the game, and the therapists and the physician reported that this method is an effective tool in the hand therapy process."

*Competitive vs Affiliative Design of Immersive VR Exergames [29]*

This paper documents the development and deployment of a VR exergame focusing on the difference between competitive and affiliative design methods. The paper highlights design principles that need to be taken into account when developing these forms of games. The paper is stating: "Sinclair and colleagues emphasized that a good balance between factors such as game's attractiveness and effectiveness is important to design successful exergames." The paper concludes that participants' motivation was high during usage, but it also states that the motivation among groups varied based on characteristics. The paper states that there is a lack of long term research in this field.

*Smartphone's psychiatric serious game - IEEE Conference Publication [30]*

The paper documents the research and development of a system that mixes serious gaming, Healthcare and mobile phones to create a writ rehabilitation application. The paper highlights the effectiveness of custom systems for rehabilitation purposes. The paper underlines the importance of involving users in the design process. The paper documents the effectiveness of this application in terms of patient motivation, engagement and effect. The paper discusses the effectiveness of converting traditional rehabilitation exercises into games but states it is difficult to create a system that fits all user cases due to the various requirements of disabled users.

*The interplay between IoT and serious games towards personalized healthcare [31]*

This paper states that the usage of exergames can strongly improve users lives. The paper documents how serious games in the future can be combined with the internet of things to allow serious games designers to create new systems that can be better personalized for individuals. The paper documents how full-body tracking systems are becoming more available for consumers, allowing mass adoption of these systems.

*Urban Exergames: How Architects and Serious Gaming Researchers Collaborate on the Design of Digital Games that Make You Move [32]*

This paper details how collaboration between stakeholders is needed to create better forms of rehabilitation exergames. The paper claims that there will be a need for exergames aimed at obese people due to the increasing population requiring assisted living due to obesity. The paper claims a market for exergames looking at the Wii sales numbers, and pokemon go user base size. The technological progress of mobile units allows the development of exergames that can take geography into account.

*Serious games in prevention and rehabilitation [33]*

This paper documents the more political aspect of using computer games in rehabilitation and how science and society have polarized its usage—the paper details concrete examples

of how exergames can improve the body. The paper documents concrete data taken from specific rehabilitation programs for various disabilities. The paper states that studies on the rehabilitation impact of VR serious games on different disabilities vary greatly, blaming it often on poor experiments and studies. The paper concludes that the existing studies show promising tendencies for additional benefits of serious games and VR on the physiological, behavioural, and psychological level but note that sustainability and long-term effects have rarely been considered.

*Eye Gaze Assistance for a Game-Like Interactive Task [34]*

This paper documents how effective games are in training users to perform certain tasks related to their disability. The paper uses hardware to provide individuals with decreased or non-existing motor functions interfaces designers can use to create serious games or other applications. The paper discusses how the usage of AI can improve their systems.

*Kinect-Based Exergames Tailored to Parkinson Patients [2]*

The paper claims that the main reason that patients drop out from rehabilitation programs is due to boredom and the required repetitive programs. Using off the shelf hardware, the researchers develop and test a rehabilitation game for Parkinson patients. The paper has problems finding quantitative results.

*design of an exergaming station for children with cerebral [35]*

This paper documents the development of an exergame tailored to children with cerebral palsy. The game was interactively designed with assistance from medical professionals, game designers, computer scientists, kinesiologists, physical therapists, and eight children with cerebral palsy. The game's initial design was only playable by 3 of the children, with the final iteration being playable by seven, with six being able to reach recommended daily exercise using this system. These results indicate that non-disabled designers are unable to create exergames aimed at groups without their design input.

*New Approaches to Exciting Exergame-Experiences for People with Motor Function Impairments [36]*

This paper documents the lack of interesting good rehabilitation games and the lack of research and development done in creating interfaces for individuals with severe disabilities. The paper highlights methods that should be considered when designing exergames to increase players' immersion and involvement.

*Design guidelines for developing customized serious games for Parkinson's Disease rehabilitation using bespoke game sensors [37]*

The paper documents the research and development of a serious rehabilitative game using off the shelf hardware systems. The system is developed using a patient-driven design approach. The system contains transitional rehabilitation exercises that have been translated into a game world. The

paper states how difficult it is to design around patients with Parkinson's Disease. The paper highlights how one of their main findings is the need to personalize and customize the systems. The paper also discusses how difficult it is to develop a system that fits everyone regarding disabled players. The paper concludes that they can measure an increase in motivation among patients who partook in the study.

***The remaining result section will discuss the various findings located in the books I researched. The results are grouped up and written in a summary fashion based on the information presented in the books; this is due to the various relevant statements being very disjointed in the book, making it difficult to present the data in a readable manner.***

*Serious Games in Physical Rehabilitation [38]*

This book documents various problems facing rehabilitation games. The book states that the objectives and techniques of rehabilitation are extremely different depending on the severity of the disease/disability and depending on the level of the lesions. The book highlights how many patients drop out of conventional rehabilitation programs due to motivational issues and states that games might increase patient motivation. The book details how games are experts at making repetitive tasks more manageable and generally improving patient feeling while performing the exercise. The book also states that these games might be too expensive for many users, making them a potentially unviable rehabilitation method for many. Regarding personalization and customization, the book details how each patient has specific needs that need to be addressed, making generalization difficult.

The book states that games are extremely important for the development of children, saying: "...games have always been present and play an important role in the society for the development of the children, for social and psychomotor development, for teaching purpose, for adults, social cohesion, learning...". The book uses concrete data to back this up and states that 97% of American children (2009) play video games.

The book details various mental and physical problems individuals who do not partake in games or exercise activities might experience in the long term.

The book details how medical science is very rigid in its belief and is very slow at adopting new hardware and software, which raises the concern that research on commercial hardware in rehabilitation will finally be done when the hardware has become obsolete.

*Serious Games Foundations, Concepts and Practice [39]*

This book details how games can be used to make boring activities fun; this can be used to increase motivation among patients regarding repetitive activities. The book claims that one of the problems facing many disabled individuals is the lack of day to day mastery; with that taken into account, games can be designed to allow the disabled player to have control and mastery inside the game world. With this in mind, the book highlights how important adaptation is when

creating serious games for disabled people, but designing systems for disabled individuals is extremely difficult. The book presents a set of guidelines regarding the physical design of exergames. The book especially highlights the importance of initial personalization of the system for extremely disabled individuals, mentioning that different stakeholders like health care professionals and caretakers need to be taken into account when designing the system. The book discusses how serious games can provide players and relevant stakeholders about the progression of the players allowing for greater adjustment during play.

The book goes into great detail on how serious games can impact various psychological aspect of the patient, especially the self-determination theory.

The book highlights two areas that lack research in terms of disabled players, and those are how to make online competitive games more accessible for disabled players and what kind of player type are common among disabled players who want to perform the exercise by using exergames.

### *Virtual, Augmented Reality and Serious Games for Healthcare I [3]*

This book covers the topic of rehabilitation very extensively. The book contains research papers from various sources and sometimes makes slightly contradictory claims. The book states that one of the most promising future trends in rehabilitation is the usage of VR and AR and the usage of off the shelf hardware. The book covers many forms of exergames designs that can be applied in the design of exergames. In terms of software, the book states that it believes in using commercial games in a modded fashion, making them more accessible for disabled users. The paper states that it is uncertain how to properly assess the progress and skill level of disabled individuals for personalization purposes. The book claims that this is highly likely due to individuals looking at VR and new technology through traditional lenses.

The book documents an EU wide initiative (the REWIRE initiative) that was created to develop and test rehabilitation games. The book contains no results from this initiative.

The book highlights how certain types of disabilities require specific needs and adaptations for their games to be playable. The book presents concrete examples of how adjustments are applied to certain conditions, but there is a lack of evenly applied research on all conditions; a concrete example is the effectiveness of VR rehabilitation on stroke patients. The book highlights disagreements between developers of serious games and clinical teams regarding the effectiveness and safety of their application. As stated by the book: "In sum, despite the positive results found in research, the evidence level of these studies is still weak, and each task needs to be revised deeply before" "jumping" into clinical practice."

In terms of hardware, the book states that for many individuals and rehabilitation centres, expensive hardware and systems to be used for rehabilitation purposes might not be possible to acquire. The book does compare VR development costs to

the usage of robotics and concludes that VR systems are a lot cheaper to produce and maintain.

On the topic of VR usage in terms of rehabilitation, the book states: "In neuropsychology, VR is used to offer a new human-computer interaction paradigm in which patients are no longer simply external observers of images on a computer screen but are active participants within realistic virtual world" adding that: "Specifically, it is possible to control and manipulate tailored exercises within meaningful, ecologically valid and motivating Virtual Environments (VEs). Indeed, VR simulations can be highly engaging by supporting a process known as transformation of flow, defined as a person's ability to exploit an optimal (flow) experience to identify and use new and unexpected psychological resources as sources of involvement. From a psychological perspective, motivation is particularly important for patients consistently engaged in demanding and practice-heavy cognitive exercises."

In terms of new possibilities, the book states that the VR space can be used to provide individuals with lost limbs the opportunity to get the lost limbs back in a virtual space, opening new possibilities for rehabilitation, stating: "In clinical terms, manipulations of a virtual body could have implications not only for motor or sensory rehabilitation but also for psychological treatment in different pathologies involving body perception, such as painful phantom limbs, regional pain syndrome (Llobera et al. in press), eating disorders, or burn". The book adds that prosthetics can be used as input devices for games; this requires standardization with hardware and software with rehabilitation in mind.

In terms of design, the book states that rehabilitation games are traditionally boring and limiting in-game experience. Indicating the need for greater support from designers, but the book highlights that exergames still allow players for better or worse to perform more activities than they want or believe they can, due to flow as indicated by the quote above.

The book states that proper rehabilitation requires more than one game, and the games require a lot of surveillance and assistance from the specialists to work properly, indicating that several stakeholders need to be taken into account when designing and deploying serious games for rehabilitation. The book states: "the development of VR technology for healthcare requires not only technical development but an understanding of the context in which the technology will be used, the people involved, and the environment, practices and processes in which it will be placed". The book brings up the possibilities of abstracting disabilities for grouping purposes, stating that abstraction allows the grouping of patients since they can share the same basic needs before the person to person customization is applied to the system and deployment easier.

The paper covers the research of the development of an online rehabilitation community, based on the idea that group rehabilitation is better than individual rehabilitation, but highlights the difficulty of balancing and personalization such a system would require with all the forms of disabilities they need to account for.

Regarding future hardware possibilities, the book states that

the complete track of various body sensors can allow data mining possibilities to push research and development of rehabilitation systems further. In regards to off the shelf hardware effectiveness, the book is unable to conclude concrete results. The book states it is worried about future technology (PS4, XBOX1) being closed-off systems, making it hard to use their hardware for custom rehabilitation software. It does state that even if the systems themselves are closed off, many of these systems come with separate hardware components that can be used on a PC system. Regarding specialized hardware, the book states that it is possible to use supportive rehabilitation equipment, and other assisted living equipment can be used as alternative game input systems.

As a concrete example, the book reports how AR can assist individuals with Parkinson by overlapping onto reality and assessing the users daily. The system was when developed realistic enough to create comparatively results when compared to reality vs VR, but the book states that the hardware was subpar and required many setups,

Another concrete example from the book is chapter 23, which provides an overview of the current state of the art and describes a field study exploring the benefits of motion-based touchless gaming for autistic children with low-moderate cognitive deficits, low-medium sensory-motor dysfunction, and motor autonomy. According to the book, their findings look promising.

## VIII. DISCUSSION

In this section, I will discuss the results from the previous section.

### *Effectiveness*

In the documented papers, the more common finding in the various studies was the observed increase in motivation and mastery among participants while partaking in rehabilitation focused serious games. A majority of the papers alluded to an observed increase in motivation in participants who usually had to perform repetitive rehabilitation tasks compared to individuals who only partook in traditional rehabilitation tasks. Many of the papers lacked accurate quantitative data and relied more on qualitative data. The observed motivational effect varied from paper to paper, but most of those who reported motivational observations, observed an overall increase, while no paper reported a decrease in motivation among users of their system.

In terms of effectiveness, in terms of rehabilitation, the papers disagree somewhat. While most of the papers stated that they observed improved patients using serious rehabilitative games, the effect observed varied from little to extreme. This might indicate a problem with how the studies were conducted, or it might indicate that different groups of individuals with different disabilities respond differently to the usage of serious rehabilitative games.

### *Application*

The various papers studied in the result section almost unanimously cover different application areas and methods

compared to one another, making comparison difficult. The papers are seemingly not relying on each other's research during system development and will deploy their system to the areas the researcher best deem fit, and not rely on healthcare personnel to deploy their system based on testing of various test groups. The papers also largely vary in their development methods, making me find it difficult to compare the systems that have been developed. A concrete example of this is how systems developed using a User-Centered Design approach had seemingly had much better results in their application testing versus systems developed using traditional development methods. Even so, most of the various systems that were developed documented improvements of various characteristics of the patients.

I want to note that I noticed a little discussion on the possibilities of increased motivation among participants due to new and exciting technologies like VR, again making me question the lack of longitudinal studies in this field.

### *Generalization and standardization*

As stated in the research motivation section, I wanted to investigate why there are no generalized platforms or standardized methods for developing and deploying rehabilitation-focused serious games. As extensively documented in the various research papers and books in the result section, disabled individuals are extremely difficult to generalize. The various forms of disabilities, even within the same group of disabled individuals, are extremely distinctive and often require highly personalized care for proper rehabilitation to take place. I found it puzzling that only a few of the papers even discussed the possibility of generalization and standardizing of their systems involving disabled individuals as a group, with none of the papers even trying to extend their systems to new user groups.

### *Observed trends*

In terms of observed trends, the papers indicate that the increased availability of high precision hardware sensors opens up the possibility for more personalized and customizable systems and serious games. The papers I reviewed mainly focused on using off the shelf hardware systems, like the Wii, PS3/4 and the Xbox 360/1 and their corresponding external systems. At the time of writing, most of these systems are either obsolete or becoming obsolete, indicating the need for more long term supported hardware systems. This is especially important since the time it can take for a system to be clinically tried and tested, the relevant hardware might become obsolete before rollout. Few of the papers observe a trend from companies and various governments in their increased interest and investment in serious games based rehabilitation programs, noting the REWIRE project and the NHS Mira Rehab project. I was unable to locate any references to this, but recently companies like Microsoft have invested in developing their adaptive controller, a highly customizable hardware system designed for disabled gamers. [40]



#### *lack of interest in adoption from a clinical perspective*

One of the more interesting results found in the various papers was the documented opposition by healthcare personnel. The technological field needs to address this issue to avoid becoming obsolete before widespread deployment and usage. With the normalization of technology in healthcare and rehabilitation, this issue will be lower, especially among older patients. Even so, the rapid technological advances need to be addressed by the healthcare community.

#### *lack of interdisciplinary collaboration*

A large section of the papers that focused on the research and development of serious rehabilitation games often relied on teams made up of mainly programmers and industry professionals. As stated by several of the documented papers, notably in "Designing a Platform for Child Rehabilitation Exergames Based on Interactive Sonification of Motor Behavior [22]", it seems very likely that the development of rehabilitation games requires many various disciplines, including user input from the user group. With this taken into consideration, the results might become less valid.

#### *Interesting new ways of rehabilitation*

Due to the vastly different areas covered by the papers, it is possible to conclude that serious games can be applied in many different areas to assist in rehabilitating and training individuals with different disabilities. These papers might indicate that it is possible to use technology in new interesting manners to develop potential effective serious games with emerging technologies.

#### *lack of testers observed*

As mentioned in the Effectiveness section, a majority of the experimental studies seemingly lacked quantifiable data. This is due to many of the papers performing their studies and experiments on small groups of testers. The reliance on small test groups was rarely discussed in the various papers, something I find strange, especially due to many papers stating that disabled individuals were unique in their needs and requirements.

#### *lack of market*

The papers never explicitly stated this, but since the various papers replied mainly on off the shelf hardware, there is an indication that there is a very small market for custom hardware created for disabled individuals. Considering the uniqueness of the various disabilities and individuals, I believe that there will be little creation of customized technology for disabled individuals in the future. With that said, there seems to be an increase in cheap, highly customizable hardware out on the market that can be used to develop serious games for disabled individuals. As mentioned in the "Playable One-Switch Video Games for Children with Severe Motor Disabilities Based on GNomon" paper, these rehabilitation systems can be sold to disabled users who can use this hardware for other forms non-rehabilitation tasks, making the system more marketable.

#### *lack of funding observed*

Building on the lack of market observation, I am under the impression that many of the studies conducted by the researcher in the result section lacked proper funding for development purposes. To again quote "Competitive vs Affiliative Design of Immersive VR Exergames": "Sinclair and colleagues emphasized that a good balance between factors such as game's attractiveness and effectiveness is important to design successful exergames." I believe that many of the games I observed in the research papers were poorly designed from a game design perspective, with some games using art assets I would personally deem unattractive. A notable example of this is the game presented in the paper "Design guidelines for developing customized serious games for Parkinson's Disease rehabilitation using bespoke game sensors". Many of the development papers covered in the result section might have been different if the games were presented more attractively. There are more features than just accessibility and gameplay that need to be considered when designing a game.

#### *Lacking longitudinal studies*

As highlighted by a majority of the papers, the timeframe of their study was often a very short amount of time, making it difficult to draw definitive conclusions out of the results. I believe that short term improvement in patients, especially regarding observed patient motivation when introduced to new rehabilitation methods, should be expected due to the papers stating that patient motivation and engagement drops due to the repetitive nature of the rehabilitation exercises. The studies need to be conducted for a long enough time that using these systems is no longer considered new and exciting but as normal as performing traditional rehabilitation exercises. I am questioning how effective these systems are at making the patients internalizing the rehabilitation exercises. Conducting longitudinal studies is expensive and difficult when considering that off the shelf gaming hardware becomes obsolete every so often.

#### *Usability of the data*

As previously discussed, the papers often rely on the usage of off the shelf hardware. These systems might become obsolete in the future, making me question how useful the data will be in developing future systems. A notable example of this is the difference between the Wii system and the Switch system.

### IX. FLAWS

This section will reflect on some of the issues I faced or performed while researching this paper.

#### *Lacking proper structure in methodology*

While performing my literature review, I mostly focused on the results and discussion found in the various papers, forgetting the need to group the papers based on their methodology, systems used, disability research Etc. This problem became apparent while writing the discussion section, but I

did not have the opportunity to go over my material again for categorization purposes due to time constraints. I believe this is the greatest flaw of my paper and should be prioritized in future papers.

#### *Difficult to find research*

I found it surprisingly difficult to find concrete research. This is a topic area that is well researched, and as seen in the result section, I was able to locate many papers. Even so, a recurring issue was that I kept finding new interesting research to add to the list whenever I was under the impression I had completed my literature review. An example of this was when I located the "Virtual, Augmented Reality and Serious Games for Healthcare 1" book at the end of my research period. This might indicate that my research methodology was somewhat faulty.

#### *lack of quantitative research methodology*

As previously discussed, many of the papers that I reviewed lacked quantitative research methodology, making it somewhat difficult to validate their findings, making me question the validity of my conclusion. It also made it difficult to make comparisons between the papers.

#### *Cultural differences*

A few papers discussed the cost factor on the usage of these systems, but I am unsure this logic fits the Norwegian healthcare system or the healthcare system of European union members. Some of the papers and the books covered in the results section were written by Americans who use a healthcare system that lacks universal healthcare.

### X. CONCLUSION

In this paper, I wanted to document and research the effectiveness of using serious games in a rehabilitative matter. This paper started with the question, "why are there no shared serious games rehabilitation platforms that aim at disabled individuals in general".

I performed a systematic literature review on research papers and books I located through various means and grouped their findings in this paper to explore my question.

By doing this, I have documented the current state of rehabilitation using serious games, and I have covered the findings of various researches and experiments.

Based on these findings, I can conclude that almost no research has been conducted on creating a shared universal platform for the rehabilitation of disabled individuals using serious games. The results overwhelmingly agree that it is extremely difficult to generalize the various disabled groups and individuals for abstraction purposes, making the development of this kind of platform nearly impossible. As highlighted in the result section, some too many stakeholders need to be involved in the rehabilitation process.

Rehabilitation is a slow, tedious and process. However, based on my findings, serious games based rehabilitation should be offered to individuals with low motivation, and it

should be used together with traditional rehabilitation exercises to lower the mundaneness of the traditional exercises. A majority of the results in the result section indicate an improvement among patients who partook in the usage of serious games in a rehabilitative matter, but the results are not conclusive, as discussed in the discussion section. As new hardware is made available, more research on the general benefits of using serious games in rehabilitation is needed.

### XI. FUTURE WORK

#### *Mirarehab*

Near the end of the deadline, I came across a system called "Mirarehab". This system is currently being used by the British National health service, stating: "The NHS is harnessing the power of information and technology to empower people to take control of their own health. This software platform – which translates existing physiotherapy exercises into video games – can help with injury rehabilitation" [41] Google Scholar contains links to papers that reviewed and researched the effect of Mirarehab, but due to this discovery happening late in the report writing, these papers have not been reviewed.

#### *Improved methodology*

As mentioned in the Flaws section, I believe a re-review is needed with a more structured approach to the methodology, improving comparison and validation of the results found in the various papers.

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