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Motion Sensors in Physical Therapy

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Preface

This report is a result of my Master thesis project titled *Motion sensors in physical rehabilitation*. This project is a cooperation between The Department of Computer and Information Science (IDI) at the Norwegian University of Science and Technology (NTNU) and St. Olav's University Hospital in Trondheim.

Acknowledgment

I wish to thank my supervisor Dag Svanæs at the Department of Computer and Information Science, Norwegian University of Science and Technology for his invaluable guidance throughout the work of this thesis. I would also like to thank Terje Røsand for his technical assistance in the laboratory and Trond Are Øritsland for his help with the carpentry of the prototype.

I am forever grateful to the physical therapists for sharing their knowledge with me, and their cooperation and enthusiasm towards my thesis. It would have been impossible for me to finish my thesis without the insight they have given me.

Gratitude is also given to Mathias Tjomsland for his help with proofreading this thesis on short notice.

Special thanks are given to my mother and father for supporting and believing in me during all years.

Finally, I want to direct a special thanks to my girlfriend, Marita, who has been patient and understanding of late nights at school and the limited time we have had together during this semester.

William Young
Trondheim, December 2010

Abstract

This thesis studies the use of off-the-shelf motion sensing technology in physical therapy rehabilitation. The aim of this thesis is to evaluate how suitable existing commercially available video gaming consoles are for use in physical therapy and explore the challenges associated with creating custom therapeutic systems based on existing platforms.

A set of qualitative data gathering activities were selected; observations, workshops, interviews and prototyping. Five physical therapists working at hospitals were selected as participants. Through these activities empirical data was obtained for further analysis and discussion.

The participating therapists suggested that existing games were only to a small extent directly applicable as treatment methods, hence custom tailored games should be developed. Patients have very different needs, and the existing games are developed with mainly healthy people in mind, and therefore it is not obvious that they are applicable as rehabilitation treatment.

To develop games for patients that need physical therapy, knowledge in this field is needed - hence the involvement of five specialists cooperating with a system developer. The findings indicate that games to be used in physical therapy ideally need to be extremely customizable by the therapists to allow adjustments to individual patient needs. This leads to a set of design guidelines for developing rehabilitation games with motion sensing input devices.

The physical therapists in this thesis are positive towards introducing Nintendo Wii to their patients, and see great potential in using the Wii as a tool in their future work.

Contents

List of Figures

List of Tables

Chapter 1

Introduction

1.1 Motivation

My primary motivation for this thesis is to help patients recover from their disability in an effective way. I want my research to bring into focus the use of motion sensors in physical rehabilitation. My goal is to make this process more fun and motivating for patients, and help them through the hard time they are experiencing during their rehabilitation.

The video game producer Nintendo introduced the Wii gaming console to the mass market in December 2006, and with the Wii console came the Wii remote control called a *Wiimote*. The Wii platform introduced the world to a more physical gaming experience, and the idea of using this technology as part of physical rehabilitation was born. For the first time these advanced devices, measuring motion and weight, can be easily obtained by almost everyone and used in rehabilitation [14]. I want to explore if it is plausible to use Nintendo Wii for physical rehabilitation and to find solutions for designing systems that can be used in physical rehabilitation.

1.2 Project Context

This project is a cooperation between The Department of Computer and Information Science (IDI) at the Norwegian University of Science and Technology (NTNU) and St. Olav's University Hospital in Trondheim. The

1

project was born as a spin-off idea after a project at the IT-University of Copenhagen about the role of digital technology in physical rehabilitation [4].

The purpose of this project is to explore how low-cost motion controlled gaming console can be used in physical rehabilitation.

The Norwegian Physiotherapist Association defines physical rehabilitation's aim "... to help persons with handicaps or chronic disease so that they can manage on their own and function socially. The aim of this process is for the patient to regain or preserve a best possible level of functionality through learning and by using their own resources"([20], my translation). The patients may have been subject to accidents or disease. One such disease may be stroke, which is an example of a disease that demands interdisciplinary cooperation for a successful recovery. Physical therapists work with rehabilitation in the patient's home, in nursing homes, and in special institutions [20].

Physical therapy constitutes prevention and treatment of diseases and physical suffering. The physical therapists have extensive knowledge of the parts of the body we use when we move, i.e. muscles, tendons, joints, the circulatory system, and respiration. The main tasks of a physical therapist is the promotion of health and disease prevention, treatment, training, and rehabilitation [20].

1.3 Research Questions

My goal in this thesis is to find the advantages and the challenges of designing systems for a low-cost gaming console to be used in physical rehabilitation. This goal can be divided into three questions. The three research questions in this thesis are the following:

1. **RQ1:** Are existing Nintendo Wii console games suitable in physical rehabilitations usage?

2. **RQ2:** What are the design challenges associated with creating systems for Nintendo Wii to be used in physical rehabilitation?

3. **RQ3:** Can the lessons learned in this project be synthesized to a set of design guidelines for rehabilitation games with motion control?

1.4 Limitations

This thesis studies using Nintendo Wii in physical rehabilitation. Other motion sensing input devices were not chosen because they either were unavailable or too expensive. This thesis is a cooperation with St. Olav's University Hospital. All the therapists in this thesis are working at a hospital, and are in that sense not representing all forms of physical therapy. The physical therapists in this project were recommended by the chief of Clinical Service at St Olav's University Hospital. There are no patients directly involved in this project; all information about the actual clinical work comes through the physical therapists.

1.5 Research Method and Approach

This study will use a qualitative research method. Qualitative research involves a methodical collection, coding and analyzing of data. It also involves an interpretative process of the data collected [5]. Qualitative methods are usually preferred if you want to do exploratory investigations, and are not too concerned about generalizing the results [41]. This strategy is used to dig deeper into a problem, understand the situations and actions, and to discover new information.

Data collecting methods includes observations, workshops, interviews, prototyping, and evaluation. This will be further explained in chapter 4.

1.6 Thesis Outline

Chapter 1 Introduction This chapter introduces the project, its domain and its context.

Chapter 2 Nintendo Wii This chapter introduces the Nintendo Wii platform. It presents the peripheral to the Nintendo Wii console, and its software.

Chapter 3 Related Products and Research This chapter presents other motion-sensing gaming consoles, and previous research in this research area.

Chapter 4 Research Methodology This chapter describes the research methodology used in this thesis and the research design.

Chapter 5 Observations This chapter considers the observations conducted in the research. The aim of the observations was to see how and where physical therapists working (the context of use).

Chapter 6 Workshops This chapter explains the planning and the execution of the workshops conducted for the project.

Chapter 7 Interviews This chapter describes the interviews with physical therapists about their experiences using Nintendo Wii in physical rehabilitation.

Chapter 8 Prototype and Evaluation This chapter outlines the prototypes and the evaluation of the prototypes in the project.

Chapter 9 Discussion In this chapter the research questions posed at the beginning of the project will be revisited. The answers based on the insight gained throughout the project will be summarized.

Chapter 10 Conclusion The conclusion drawn, based on the findings in this project is presented. Suggestions for further research within this area is discussed in this chapter.

Chapter 2

Nintendo Wii

This chapter introduces the Nintendo Wii platform (Section 2.1) and its motion controller (Section 2.2). The next section explains its expansion device (Section 2.3), and further section describes another accessory named Wii Balance Board (Section 2.4). The last section in this chapter presents some of the Nintendo video games used in this project (Section 2.5).

2.1 Nintendo Wii Home Video Gaming Console

Nintendo released their Nintendo Wii home video gaming console (see Figure 2.1) in December 2006 [35]. The popularity of this gaming console has been enormous, with sales reaching over 50 million units worldwide in 3 years [35]. The Wii console was designed to be simple to use, built on a vision that children with their parents and even grandparents could play together. Wii introduced their innovative input device, the Wiimote (explained in Section 2.2), which was designed to be easy to grasp and to point with, and making the device seem more familiar to the non-gaming public. This broadens its use to nontraditional audiences such as the elderly and disabled people. The Nintendo Wii gives gamers and traditional non-gamers a chance to play together.

The Nintendo Wii console is the smallest video gaming console to date. It measures 44 mm wide, 157 mm tall and 215.4 mm deep in its vertical orien-

tation (see Figure 2.1), slightly larger than three DVD cases stacked together [2]. The hardware is summarized in Table 2.1.

Figure 2.1: Nintendo Wii Remote (Wiimote) and a Nintendo Wii Console

CPU	IBM PowerPC 729 MHz
GPU	ATI "Hollywood" graphics 243 MHz
	NEC ARM9 470 MHz
Storage	512 MB Internal Flash Memory (Nand)
Main Memory	88 MB
Wifi	802.11 b/g
Other	Bluetooth, 2 x USB 2.0 and SD/SDHC memory card slot

Table 2.1: Nintendo Wii hardware summary

2.2   Nintendo Wii Remote

Figure 2.2: Nintendo Wii Remote control

One of the most interesting aspects about the Nintendo Wii platform is the Nintendo Wii remote control (see Figure 2.2). The Nintendo Wii Remote, often called a "Wiimote" is the primary controller for Nintendo Wii console. The Wiimote is designed to be used with one hand and its shape resembles a TV remote control. The shape is made like this to help to appeal to a broader audience. It uses Bluetooth radio signals to wirelessly communicate with the Wii console, and has a range as far as 10 meters [51]. The Wiimote has the ability to sense acceleration along three axes with the use of accelerometers [59]. An accelerometer is a transducer that detects a scale of force (accelerations). Because the Wiimote has three accelerometers, force can be detected when it is moved forwards, backwards, left, right, up, down or a combination of those. This adds up to the often mentioned "3 axes" that the Wiimote has (see Figure 2.3). Because of these accelerometers, the controller is able to detect different kind of movements (see example on Figure 2.4).

The Wiimote also contain a camera chip, allowing it to determine where the Wiimote is pointing. With this the Wiimote is able to provide a high-resolution and high speed tracking of up to four simultaneous IR light sources

from a sensorbar. [32]. The sensorbar (see Figure 2.6) contains 2 groups of IR LEDs and it is placed near a TV, and is tracked by the Wiimote to provide a two-dimensional plane for the Wiimote. The sensorbar keeps track of the controllers orientation in relation to the screen, thus allowing pointing and clicking. There is a cable from the sensorbar to the Wii console, but there is no communication between those devices. The cable from the Wii to the sensorbar is only used to power up the IR LEDs. The Wiimote has 12 buttons, a vibration motor for tactile feedback, 4 LEDs for visual feedback, a speaker for auditory feedback, Bluetooth connection, an internal flash memory, and an expansion port.

The Nunchuk is the first attachment released for the Wiimote (see Figure 2.5). It connects to the Wiimote via a cable to from its expansion port. Its appearance when attached resembles a nunchaku, hence the name. It features an analog stick and two trigger buttons. It works in tandem with the main controller in many games. Like the Wiimote, the Nunchuk also provides a three-axes accelerometer for motion-sensing and tilting.
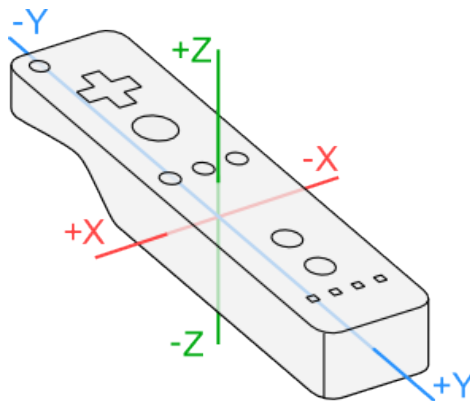
Figure 2.3: Wiimote with axis shown

Figure 2.4: Wiimote motion sensing

Figure 2.5: A player holding a Nunchuck and a Wiimote

Figure 2.6: Wii Sensorbar with TV and a Wiimote

2.3   Wii Motion Plus

Wii Motion Plus was released in 2009 as an expansion device for the Wiimote. It attaches onto the existing original Wiimote (see Figure 2.7). Wii Motion-Plus has increased precision and motion-sensing capabilities compared to the original Wiimote, as it can more accurately track the user's arm position and orientation in real time on the screen [26].

The device incorporate two gyroscopes. A two-axes gyroscope which can determine pitch and roll motion, and a single axis gyro for the yaw motion. Pitch is the rotation when the front and back goes up and down, roll is when the Wiimote tips left and right, yaw is when the front oscillating left and right (see Figure 2.7b). With this expansion device, Wiimote is able to track arm motions much more precisely [54] with 6 axes of freedom.

Figure 2.7: Wii Motion Plus

2.4 Wii Balance Board

The Wii Balance Board was released in April 2008, and it is shaped like a household body scale (see Figure 2.8). Similar to the Wiimote, the balance board uses Bluetooth technology to communicate with the Wii console.

The Balance Board contains multiple pressure sensors that are used to measure the user's center of balance and weight. Four pressure sensors (one in each corner of the board) gives the balance boards four degrees of freedom 2.8. However, the balance board is an isometric input device, and one cannot accurately control the individual degrees of freedom separately. During normal use, the balance board supports the user's weight, and the user cannot increase the pressure on one sensor without also decreasing the pressure on other sensors [12].

Figure 2.8: Wii Balance Board

The software made for the balance board can discern several different types
of movements and postures, for example:

- Balancing on one leg

- Leaning the body

- Rotating the hips

- Moving body to rhythm

- Sitting (see Figure 2.9a)

- Kneeling (see Figure 2.9b)

- Hands on the balance board (in a push-up position)
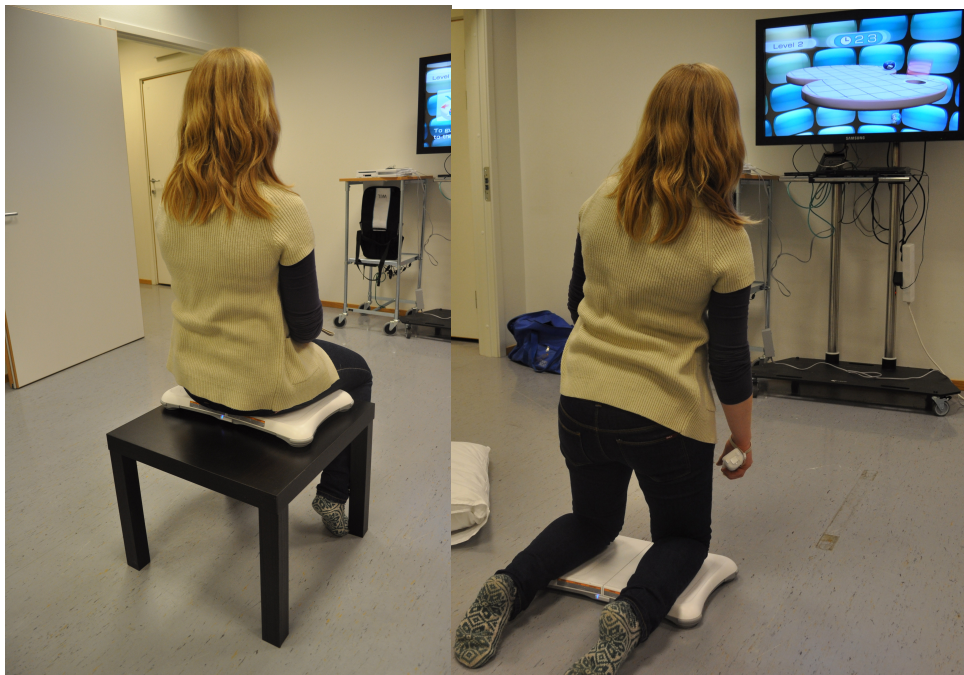
(a) Sitting   (b) On Knee

Figure 2.9: Illustrational photos of example of Wii Balance Board usage from
the NSEP laboratory.

2.5 Wii Games

2.5.1 Wii Sports

Wii Sports is a sports video game developed by Nintendo as a launch title for the Nintendo Wii in 2006. The game is a collection of five sports simulations and is designed to demonstrate the motion sensing capabilities of the Wiimote. The five sports included are tennis, baseball, bowling, golf and boxing.

The players use the Wiimote to mimic the actions performed in these sports activities. Players hold the Wiimote, and move their arms to control the actions of a Mii [37] on the screen. A Mii is a personalized digital avatar for Nintendo's Wii video game console (see Figure 2.10). The rules of the different sports are simplified to help gameplay. Similarly, the motion required for control is stripped down to an easily recognizable simplification of the real world motion being simulated. For instance in the tennis game the players use the Wiimote as they would a tennis racquet, swinging it as the tennis ball approaches their avatar, but not using their legs to move the avatar around. In baseball, the player only has to pitch the ball, and swing the baseball bat. Figure 2.11 shows the game baseball and a player holding the Wiimote.

Figure 2.10: Nintendo Mii of a player

Figure 2.11: A player playing Wii Sport Baseball

2.5.2   Wii Sports Resort

Wii Sports Resort is a sequel to Wii Sports. It was released in 2009 and is bundled with Wii Motion Plus (described in Section 2.3). Wii Sports Resort is a collection of 12 different activities. These activities are swordplay, wakeboard, frisbee, archery, basketball, table tennis, golf, bowling, power cruising, canoeing, cycling and air sports.

The game is made to demonstrate the capabilities of the provided Wii Motion Plus. The device enables 1:1 control that allows the games to be played with greater accuracy, than the original Wiimote as the Mii now follows the players hand motion much more accurately. For example, in Wii Sport Tennis, the player's shot was only determined by the direction of the swung of the Wiimote, while in the Wii Sport Resort Table Tennis, the player has a much greater control, and can add adds spins to the ball by twisting the Wiimote while swinging.

2.5.3 Wii Fit Plus

Wii Fit is an exercise game consisting of activities using a Wii Balance Board peripheral (described in Section 2.4). Wii Fit Plus was released in October 2009 and is an enhanced version of the original Wii Fit. The games are divided into the four categories yoga, strength training, aerobics, and balance games.

Each players can set a goal of how much weight they want to loose and then track the progress of how much they have played the game and whether or not they have reached their goal. There is also a multilayer mode where several people can play together and compete with each other. These scores are not saved, and will be erased when the player turns off the game.
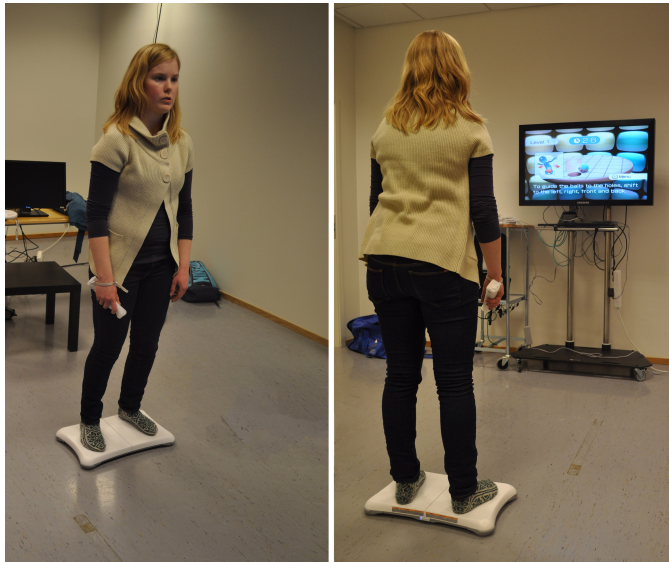
Figure 2.12: A player using Wii Balance Board playing Wii Fit - Table Tilt

Chapter 3

Related Products and Research

This chapter has two sections. Section 3.1 shows other motion controllers in video game industry and Section 3.2 shows previous research with motion controlling devices in human-computer interaction and this research field.

3.1   Related Products

Nintendo Wii with its Wiimote is not the only motion controlled video gaming device on the market. Nintendo Wii's main competitors are Sony PlayStation 3 and Microsoft Xbox 360. This section will describe some competitive products with motion control from them.

3.1.1   PlayStation EyeToy

PlayStation EyeToy (see Figure 3.1a) is a color digital camera device, similar to a webcam, for the Sony PlayStation 2 (PS2). The technology uses computer vision and gesture recognition to process images taken by the camera. This allows players to interact with games using motion and color detection. It also has a built-in microphone so that voice and sound can be used to interact with the PS2.

EyeToy was first demonstrated for public in 2002, and later released in Europe in 2003, bundled with EyeToy: Play. In 2007 Sony released their EyeToy for PlayStation 3 (PS3) and its new name is PlayStation Eye (see Figure 3.1b). This webcam is similar to the old EyeToy, but with four times the resolution, and two times the frame rate and sensitivity. There has been numerous studies using EyeToy in rehabilitation, for instance [25], [11], [40].

(a) PlayStation EyeToy   (b) PlayStation Eye

Figure 3.1: PlayStation Eyetoy 1. and 2. generation

3.1.2   PlayStation Move

PlayStation Move (see Figure 3.2) is the most recent device by Sony PlayStation (September 2010). It is designed to be used with PlayStation 3, and it is bundled with a new PlayStation Move controller and a PlayStation Eye (described in Section 3.1.1). The PlayStation Move motion-sensing game controller is similar to Nintendo's Wiimote.

Like Nintendo's Wiimote, the PlayStation Move controller also has a three axes accelerometer and a three-axes angular rate sensor. The main difference is that the PlayStation Move controller have a glowing sphere that emits light. The PlayStation uses the PlayStation Eye to detect the glowing sphere's light, and through this detects the controller's motion and position.

The glowing sphere will give an absolute location in physical space for the system to peg all the other data to. Simple left and right movement of the light from the sphere can tell the system where you are on an X and Y axis, while the size of the sphere tells the system how close or far you are from the PlayStation Eye, the Z axis. The PlayStation attaches all the accelerometer and gyroscope data to that point in space.

Figure 3.2: PlayStation Move

3.1.3   Microsoft Kinect

Kinect for Microsoft Xbox 360 is a controller-free gaming and entertainment device released during the fall of 2010. This is based on a camera peripheral for the Xbox 360 video gaming console. It enables users to control and interact with the Xbox 360 without a game controller, through a natural user interface using gestures, voice commands, or presented objects and images.

The technology behind Kinect is a combination of software and hardware contained within the Kinect sensor accessory (see Figure 3.3) that can be added to the Xbox 360 console. The Kinect sensor is a flat black box that sits on a small platform, placed near the television. The Kinect sensor contains three important pieces of hardware:
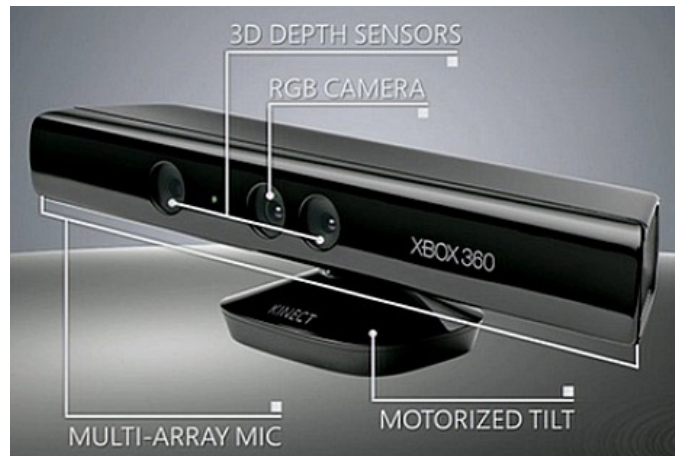
Figure 3.3: Picture of Kinect Sensor from Xbox.com

- Color VGA video camera - This video camera aids in facial recognition and other detection features by detecting three color components: red, green and blue.

- Depth sensor - An infrared projector and a monochrome CMOS (complimentary metal-oxide semiconductor) sensor work together to "see" the room in 3-D regardless of the lighting conditions.

- Multi-array microphone - This is an array of four microphones that can isolate the voices of the players from the noise in the room. This allows the player to be a few feet away from the microphone and still use voice controls.

Figure 3.4: A hand with lights emitted from Kinect taken with a night vision camera

The infrared projector sends out thousands of invisible IR light spots (see Figure 3.4), that the camera sees, which is then analyzed by the software.

Kinect's software layer is the essential component that adds meaning to what the hardware sees. It can detect the room and configure the play space the user will be moving in. Then Kinect detects and add up to 48 points on each player's body, mapping them to a digital reproduction of that player's body shape and skeletal structure (see Figure 3.5) [10].
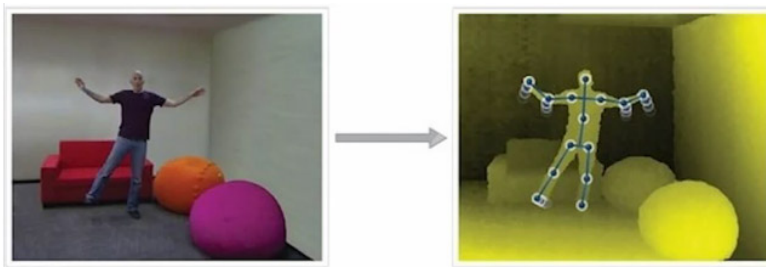
Figure 3.5: Body Mapping

Microsoft has officially welcomed its customer to make their own software for Kinect.

Shannon Loftis, studio manager at Microsoft Games Studios [6]:

"As an experienced creator, I'm very excited to see that people are so inspired that it was less than a week after the Kinect came out before they had started creating and thinking about what they could do."

It looks like Microsoft has no plan to prevent or stop the development from users of Kinect. Only a few days after Kinect's launch many people have designed their own application using Kinect and a Microsoft Windows 7 PC. This more open and programmable platform suggests that development of rehabilitation games might be an easier process using this Microsoft technology.

Just as the Nintendo Wii, Kinect's games are developed for healthy players, and are thus not necessarily suitable for patients for use in physical therapy. Current Microsoft Kinect games commonly assume that the player is able to stand, has a good sense of balance, and has reasonably good control of both upper limbs. These initial physical requirements restrict usage by many disabled people.

3.2   Related Research

This section will first present Nintendo Wii used in HCI research, and second present previous research done with Nintendo Wii in physical rehabilitation. This will in Section 4.3.3 and Section 9.4 be compared with my research.

3.2.1   Research using Nintendo Wii

Nintendo Wii is a versatile system. Despite the fact that Nintendo Wii is only four years old, there have been numerous researchers in different research fields who have seen the potential with using Nintendo Wii. Some of them are presented below.

In pedagogical tools research, Pearson has evaluated the potential of the Nintendo Wii to support disabled students in education [37], and Holmquist's research [28] uses Nintendo Wii as a tool to teach physics and natural science to students.

Sahar's study [43] tries to increase the interaction in sensor based systems, and has identified design issues on Nintendo Wii. Farley [17] explores how these new motion sensing technologies allows users to interact with 3D immersive spaces using more natural human movements with haptic feedback. Gamberinis' [21] paper aims at providing an overview of studies investigating the relationship between game activity and cognition on when computer

games. Wong et al. (2008) [60] has studied how one can use the Wii controllers as a musical instrument in an interactive music performance system.

3.2.2 Research using Motion Sensors in Physical Rehabilitation

One of the main research areas concerning the Nintendo Wii is in the research field physical rehabilitation. The popularity of this research field is increasing, and is of interest both in the technological and medical communities.

Deutsch et al. describes in [14] the feasibility and outcomes of using a low-cost, commercially available gaming system (Wii) to augment the rehabilitation of an adolescent with cerebral palsy.

Goldberg et al. [24] studied an approach to motivate patients with acquired brain injury (ABI) to participate in therapeutic activity using Nintendo Wii and the stock game Wii Sport Bowling.

Ramchandani et al. [39] and Szabo et al. [50] found positive results, experimenting with patients using Wii in rehabilitation exercises.

Decker et al. [13] describes the design and implementation of a Wiimote based game system to be used rehabilitating impaired range of motion in the wrist. The system was evaluated by two physical therapists, and they both agreed that it would greatly facilitate the rehabilitation process for patients.

Gil et al. [23] developed a system named Easy Balance Virtual Rehabilitation System that utilizes the Wii Balance Board as the platform for a virtual rehabilitation system designed to be used in patient's home. The system was designed based on feedback and suggestions from physical therapists. The system carries out exercises specifically designed to rehabilitate postural instability and balance disorders.

Lange et al. [31] carried out initial usability evaluations for off-the-shelf games and a prototype games specifically developed for people with specific disabilities. A series of studies were undertaken through evaluation and focus group research with a sample of people recovering from spinal cord injury, traumatic brain injury and stroke. These findings showed that the use of virtual reality and video games for rehabilitation offers potential for motivating patients to perform specific therapy tasks.

Yang [61] and Alankus et al.[1] studied the possibility of developing different games for use in rehabilitation with stroke patients. Yang uses Wiimotes and webcams to track movements and import them into computer games to help patients recover occupational functionality. Alankus et al. describes a formative study about designing and user testing stroke rehabilitation games with both stroke patients and therapists.

Anderson et al. [3] designed a few games in what they called a Virtual Wiilab - used to record performance and behavioral measurements of patients in physical rehabilitation. The conclusion was that Wii offered promising alternatives to traditional rehabilitation techniques, but suffered from problems that prevent widespread adoption.

Clark et al. [7] compared the use of Wii Balance Board versus the 'gold standard'-a laboratory-grade force platform (FP). Thirty subjects without lower limb pathology performed a combination of single and double leg standing balance tests with eyes open or closed on two separate occasions. The study shows that the Wii Balance Board exhibited excellent test-retest reliability for center of pressure and possessed concurrent validity with laboratory-grade force platform.

Fung et al. [19] investigated perceptions of occupational therapists and physical therapists on the use of Nintendo Wii in rehabilitation. The study explored four Wii games that addressed physical movement, balance, coordination, and cognitive performance. The therapists favored the use of Wii in rehabilitation as an adjunct to traditional therapy because it is therapeutic, engaging, and might increase patient participation in rehabilitation.

Saposnik et al. [44] compared two groups of stroke patients lacking arm motor improvement. The Nintendo Wii gaming system was compared to traditional recreational therapy (playing cards, bingo, etc.). The conclusion was that gaming technology represented a safe, feasible, and potentially effective alternative to facilitate rehabilitation therapy, and that it promoted motor recovery after stroke.

All this previous work highlights important implications about the potential for this project to utilize the benefits using games in physical therapy. The related research is summed up in Table 3.1.

Project	Technology	Patient group	Research aim
Deutsch et al. (2008) [14]	Wii with Wii Sport	Adolescent with CP	Rehabilitation in both standing and sitting position
Goldberg et al. (2008) [24]	Wii	Acquired Brain Injury Patient	Acquired Brain Injury Rehabilitation rehabilitation
Ramchandani et al. (2008) [39]	Wii games	Patients	Dynamic sitting and standing improvement
Szabo (2008) et. al[50]	Wii Sport	Aphasia patient	Communication
Decker et al.(2009) [13]	Wiimote, IR LED Circuit board	Stroke , Wrist fracture	Wrist movement rehabilitation
Deutsch et al. (2009) [15]	Wii with Wii Sport and Wii Fit	Post Stroke	Balance and Mobility rehabilitation
Gil-Gomez et al. (2009) [23]	Wii Balance Board	Balance disorder patient	Game development for balance disorder patient
Lange et al. (2009) [31]	Wii, EyeToy	Spinal cord injury, brain injury and stroke	Physical rehabilitation
Yang (2009) [61]	Wii and webcam	Stroke patients	Game developing
Alankus et al. (2010) [1]	Wii	Stroke patients	Game developing
Anderson (2010) et al.[3]	Wiimote and Balance board	Occupational Therapy	Gamedesign
Clark et al. (2010) [7]	Wii Balance Board	Balance disorder patients	Compare Wii Balance Board with traditional tools
Fung et al. (2010) [19]	Wii	Occupational Therapy	Survey of utility of Wii in rehabilitation
Saposnik et al. (2010) [44]	Wii	Stroke patients	Compare Wii rehabilitation with traditional method

Table 3.1: Motion sensor in physical therapy research

Chapter 4

Research Methodology

A description of the research methods used in this thesis are presented in this chapter. In addition to this the research design will be briefly discussed in Section 4.3

4.1 Overview of research methodology

Most research methods can be placed in one of the two main categories, quantitative and qualitative methods [36]. Quantitative methods are used when one seeks a broader understanding of a phenomenon. For example testing a hypothesis statically or testing a causal connection. This is usually achieved through statistical methods to verify or falsify a hypothesis. Qualitative methods are used when a deeper understanding is needed, and one wants to know more about a phenomenon. The aim could be to understand human behavior, thoughts, actions, experience or expectations. To achieve this, the researchers have to use themselves as instruments by interviewing and observing the users.

All of the methods used in this thesis fall under the category qualitative research methods, but simultaneously, quantitative data can be generated from them. Data collection is a key part of user-centered activities to identify needs and establish requirements and make evaluations [45]. The primary methods in my thesis are workshops, focus groups, interviews and observations. The information obtained from an activity will be used to prepare and to execute the next activity, which will further generate more qualitative data. These

methods were selected to encourage more detailed responses from users about the system design presented, in terms of usability, user value, attractiveness, touch and feel, and user commitment. The methods further help to explain the user experience of the product to the researcher.

4.2   Qualitative research

Qualitative research involves a methodical collection, coding and analyzing of data. It also involves an interpretative process of the data collected [5]. This strategy is used to dig deeper into a problem. Its aim is to understand situations and actions, and hence discover new information. This requires a close proximity to the object of study and thus a large sample is difficult to achieve.

After the data are collected it is often claimed that the data need to be processed before analysis can begin. For a student it is hard to know what to do with the enormous amount of qualitative data, and it is not unusual for a student who takes this approach to not know what to do with the data [8]. Qualitative research requires decisions about how the analysis should be done. Discussion of data analysis is often the weakest part of a qualitative approach and often provides little information into how the analysis is actually done. Conclusions, when data analysis has not been discussed clearly enough, often seem to appear through magic [36].

Qualitative research methods are often a result of an exploratory research approach.

Robson [42] explains that in an exploratory process, the purpose of research is:

- *To find out what is happening, particularly in little-understood situation.*

- *To seek new insights.*

- *To ask questions.*

- *To asses phenomena in a new light.*

- *To generate ideas and hypothesis for future research.*

- *Almost exclusively of flexible design.*

and Svanæs [48] adds:

> *"a qualitative study should start out with an openness towards the phenomenon, and allow for a theory to emerge from the data"*

4.2.1 Observation

Observation is a good data generation method, when the aim is to find out what people actually do, rather than what they say they do. The researcher is able to study the action of the objects, but the method through observation alone will not be able to give the cause of the action.

There are two main types of observation methods, namely, *'overt'* and *'covert'* observations. An overt observation is one in which the participants know that they are being observed; whilst participants in a covert observation do not know that they are being observed. Both observation methods have their advantages and disadvantages. In a covert observation the researcher can be sure that object of study are behaving naturally. At the same time, it is vital for the researcher to ensure that no one discovers that they are being observed. When an overt observation is selected, participants of the observation give their consent; in that sense an overt observation is more ethically correct. A reoccurring challenge to researchers conducting overt observations, is that there is little or no way to know whether, and to what extent, the participants have changed their behavior as result of knowing that they are being observed [36].

4.2.2 Interviews

An interview is a conversation between one or more persons where the interviewer asks questions to get information from the person being interviewed. The questions are designed by the interviewer to obtain the information and insight necessary for the research being done.

Interviews can be a useful technique to obtain detailed information about a particular complex topic. One can get information about feelings and experiences that can be difficult to obtain otherwise [36]. Interview as a data

collection method is a very time consuming process, one must first arrange an interview, prepare questions for the interview, conduct the interview, and transcribe the interview before the analysis can be done. The goal of using the interview method is that the interview will provide a large amount of information, so that only a small number of interviews are required. The interview should preferably be recorded, if the interviewee allows it, so that the one can go back and analyze it [36] without losing information. Relevant non-verbal information should be noted down during the interview.

There are different types of interviews. Structured interviews use predetermined, identical questions for every interviewee, whilst in an unstructured interview; the researcher has less control, and only introduces a topic. The interviewee is then allowed to talk freely, preferably with few interruptions.

Between these extremities exist the methods of semi-structured interviews where a list of topics or questions is prepared, but the order can be changed depending on the flow of the interview. Additional question can be asked when needed. This method is most suitable when the researcher has some knowledge about the topic, but also wants to discover new information. Semi-structured interviews are used in in-depth investigations.

Unfortunately interviews have some drawbacks. Both the interview itself and the transcribing afterwards takes a lot of time. The interviewee may for several reasons not give honest and complete answers. Therefore, with this in mind, interviews should only be conducted on key people in the research, and should in any case kept at a minimum [36].

4.2.3   Participatory Design Workshop

In a participatory design workshop the developer will invite the users to take part in the design process. Involving the user is a very important component of a user-centered design process.

In this type of workshop, the users are asked to design the system through scenario building and low-fidelity prototyping. The developer not only asks the user for opinions, but actively involves them in the design and decision making process. The role of the facilitators and developers is to enable the users to articulate their understanding of the context and their ideas for new solutions. This method gives the developer unique insight into the topic from the user's point of view [49].

According to iso13407:1999 [30], a human-centered design approach is characterized by:

1. the active involvement of users and a clear understanding of user and task requirements;

2. an appropriate allocation of function between users and technology;

3. the iteration of design solution;

4. multi-disciplinary design.

Further iso9241 [29] describes the importance of involving users in design:

> Iso9241-210:2010 4.3:
>
> *Involving users in design and development provides a valuable source of knowledge about the context of use, the tasks, and how users are likely to work with the future product, system or service. user involvement should be active, whether by participating in design, acting as source of relevant data or evaluating solutions (...) The effectiveness or user involvement increases as the interaction between the developers and the users increases.*

There are many opinions of how much the developer should actually take part in the design process. The developer can be

- an observer and let the participants design what they want after a short introduction.

- a facilitator and guide the participants through the process.

- a participant and make the design together with the other participants.

Different levels of involvement will lead to different results. How much involvement is needed from the developer depends on the knowledge and background of the participants. A participatory design workshop is a good method to help generate initial prototypes when the users have a lot of knowledge that needs to be extracted to make the prototype.

4.2.4   Prototyping

Prototyping is a time efficient research method in human-computer interaction [16]. Prototyping is a method that is often used in system development, and has many advantages. In early stages of the design process, prototypes are used to show the intended functionality and features of a product. To do this prototypes either emulate or have a limited set of functions compared to the final system. A prototype's purpose is to allow users of the software to evaluate developers' suggestions for the design of the eventual product by actually trying them out, rather than having to interpret and evaluate the design based on descriptions.

The prototype development is an iterative process, consisting of several sub activities, carried out in sequence. At the end of the sequence, the need for iteration is evaluated by considering the requirements to the prototype. If some requirements are added or altered, a new iteration is required.

The technique employed for developing the prototype is referred to as rapid prototyping. Starting with the requirements, a basic prototype is created. The main purpose of rapid prototyping is to create a prototype that can be used to collect information about requirements and the adequacy of possible designs [38]. Rather than spending resources focusing on the technical details of the implementation of the system, one can focus of the functionality and presentation, to allow users of the software to evaluate the developer's proposals for the design [53].

For a researcher, this method is *explorative*. A researcher learns more about the subject in the process of prototyping.

4.2.5   Focus group evaluation

Focus groups are a research technique to collect data through group interaction on a topic determined by the researcher.

A focus group consists of a number of participants who are led by a facilitator. The facilitator leads the group of participants through a discussion on a set of questions regarding the system. A typical focus group lasts a couple of hours, and covers a range of topics that is decided on beforehand. With this method, the researcher can gain knowledge about the participants' attitudes, beliefs, desires, and their reactions to ideas and prototypes [52].

The facilitator should determine the goals and the objective beforehand, to make it easier to guide the group back onto the topic if the discussion were to go off-topic. The questions should be open-ended and invite to discussion between the participants. A good aid is to film the entire process, and have several people take notes. The data gained from a focus group is qualitative. Like other methods based on asking users what they want, a focus group can produce inaccurate data because the users may think they want one thing when they really need another. Also peer pressure and group think and similar effect may come into play in certain group situations [34].

4.3 Research Design

The following sections will describe the research design used in this thesis (Section 4.3.1), and previous researches (Section 4.3.3).

4.3.1 Research Design in this Thesis

In this study an exploratory approach was elected due to its relevance to the research topic. This study mainly uses qualitative methods. This was chosen to achieve an in-depth research about using a low cost gaming console in physical rehabilitation. Thus this research approach can be described as a qualitative research where motion sensor technology is explored with physical therapists in a hospital. The overall strategy will be to start rather general and hence allow knowledge and specific ideas to emerge through the research activities.

To do this, expertise knowledge in physical therapy is needed, and thus five physical therapists were invited to join the project. They were selected from different fields and hence work with different kinds of patients in their work situation. The physical therapists had backgrounds ranging from work with children, teens, orthopedic patients, stroke patients, and CP patients. To answer the research questions stated in chapter 1.3, some research methods were found suitable:

1. Observation

2. Participatory Design Workshops

3. Interviews

4. Prototyping

5. Evaluation of Prototype

As an overall research approach, the Human-centered design for interactive systems (ISO9241-210) [29] was used (see Figure 4.1).
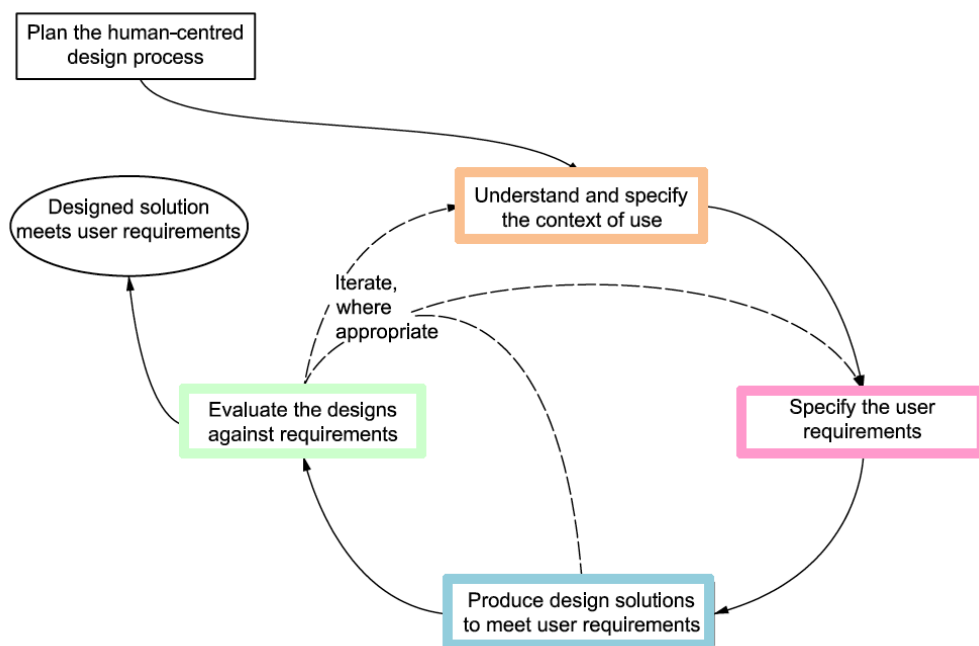
Figure 4.1: Interdependence of human-centered design activities [29]

From Iso9241-210:2010, 4.4 [29]:

Feedback from the users is a critical source of information in human-centered design. Evaluating designs with users and improving them based on their feedback provides an effective means of minimizing the risk of a system not meeting user or organizational needs (including those requirements that are difficult to specify explicitly). Such evaluation allows preliminary design solutions to be tested against "real world" scenarios, with the results being fed back into progressively refined solutions. User-centered evaluation should also take place as part of the final acceptance of

> *the product to confirm that requirements have been met. Feedback from users during operational use of identifies long-term issues and provides input to future design.*

This study applies the method research-through-design in its empirical research [62].

> *Following a research through design approach, designers produce novel integrations of HCI research in an attempt to make the right thing: a product that transforms the world from its current state to a preferred state. This model allows interaction designers to make research contributions based on their strength in addressing under-constrained problems.*

The aim of this study is to find the answer of the research questions through a design process. It was not known in advance which activities that would answer which research questions, but it was assumed that the selected activities would give relevant information to answer the research questions. This is discussed further in chapter 9.

Three workshops were carried out with the therapists. The data gathering methods included observations of the physical therapist's workspace, interviews in the workshops, and observations of the workshop activities.

As described in iso9241, the feedback of the users was very important and the users played a central part in the design and development process. As shown in Figure 4.1, the initial planning was done prior to discussing the context of use with the therapists, during the introduction workshop. The user requirements were specified through design workshops and focus groups. Prototypes were produced as possible design solutions. Evaluations of the designs were obtained through workshops and interviews. The evaluations suggested improvements to the design which were then implemented, revealing the iterative structure of the process, as shown in Figure 4.1.

The activity timeline is shown on Figure 4.2. The technology introduction was carried out first, and was meant to introduce the technology to the physical therapists to invite them to further cooperation. This is detailed in Section 6.1. The goal of the iterative prototype process is to produce sound design solutions. This process is described more fully in Section 8.1. The observations of the therapists workspace was carried out to understand

the context of use, whilst the participatory design workshop was used to obtain requirements from the therapists. The interviews and the evaluation workshop provided valuable evaluation and feedback on the design. All of the activities, even though they each had their own main purpose in relation to the design process as shown above, contributed significantly to the general understanding and development of the system.

The complexity of human-computer interaction means that it is impossible to specify completely and accurately every detail of every aspect of the interaction at the beginning of development [29].

Activity	March	April	May	June	August	September	October	November
Tech Intro Workshop 1								
Prototype 1								
Observation 1								
Observation 2								
Part. Design Workshop 1								
Prototype 2								
Workshop 3								
Prototype 3								
Interview 1								
Interview 2								
Prototype 4								
Evaluation of Prototype								

Understand context
Specify requirements
Produce design solution
Evaluate design
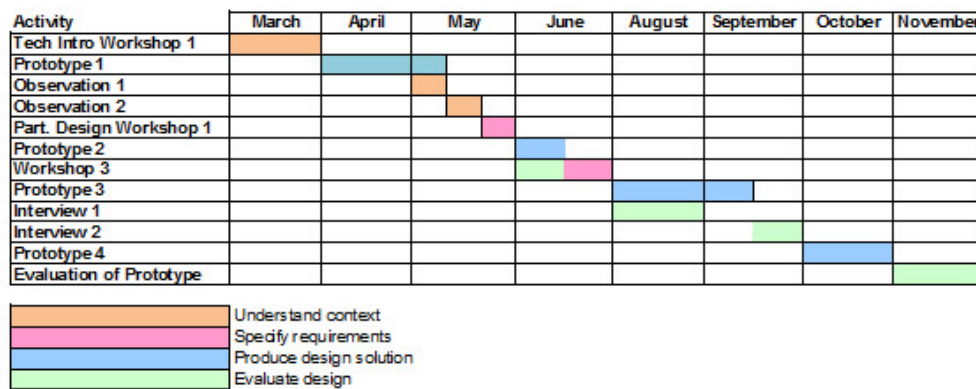
Figure 4.2: Research design timeline

4.3.2   Ethics and Privacy in this Project

The ethical aspect has been considered, during the design of the research project. The participants of this study have given their written consent to participate in the project. The written consent in Norwegian can be found in Appendix D. They were given the right to not participate, and the right to withdraw at any time. The participants were informed the purpose of the research and why it was being undertaken.

The researcher has signed a non-disclosure agreement (see Appendix E), to not reveal any confidential information that can be obtained during the project.

The information obtained in this project is kept confidential. Videos have been recorded during the workshop and are used to provide a more complete

record of events during the workshop, so that it can be analyzed by the researchers.

No patients were directly involved in this project, and all information about the actual clinical work comes through the physical therapists.

4.3.3 Research Methods in Related Research

The previous research done with Nintendo Wii in physical rehabilitation is presented in Section 3.2.2. Below is a table of the methodology the researchers used in their studies.

Project	Research methodology
Deutsch et al. (2008) [14]	Case study, 2 patients participated
Goldberg et al. (2008) [24]	Quantitative research
Ramchandani et al. (2008) [39]	Quantitative research, 4 patients
Szabo (2008) et al. [50]	Quantitative research, 19 patients
Decker et al. (2009) [13]	System development, evaluation of system by physical therapists
Deutsch et al. (2009) [15]	Case study, 11 patients participated
Gil-Gomez et al. (2009) [23]	User-centered design, with feedback from physical therapists
Lange et al. (2009) [31]	Focus group, evaluations, observations, questionnaires,
Yang (2009) [61]	Prototyping
Alankus et al. (2010) [1]	Exploratory research on 4 patients
Anderson et al. (2010) [3]	System development
Clark et al. (2010) [7]	Quantitative, 30 participants
Fung et al. (2010) [19]	Survey to therapists
Saposnik et al. (2010) [44]	Quantitative, 110 patients

Most of these research papers ([14], [15], [7], [19], [31], [39], [44]) use existing commercial games for the Nintendo Wii, which is very interesting in answering RQ1. The difference between my methodology and their methodology is that their research includes the direct use of actual patients while my thesis is based on feedback and comments from physical therapists.

There are only a few of the research papers ([1], [3], [13]) shown above who have tried to develop custom systems for Nintendo Wii for rehabilitation. The common thing between their research and mine, is the use of PC as a platform, using Nintendo Wii's peripherals, like the Wiimote or the balance board. More detailed comparison between my research and previous research done is discussed in Section 9.4.

Chapter 5

Observations

This and the following chapters will describe the implementation of the primary empirical methods, detailing the sequence of events and how it allows testing of the hypothesis. Relevant context information is needed to describe what actually happened during an event. When not given the context, the reader cannot fully understand how the described phenomenon emerged and happened. From the field of anthropology, and ethnographic field studies, the term *thick description* explains much of the same, that is to say giving a thorough description of the environment and context of the event [22]. In my thesis, I will try to use thick descriptions so that the reader can more fully understand the context.

This chapter is about the two observations conducted in the research. The goal of the observation was to see how and where physical therapists work (the context of use). The observation was done openly, and without patients present. To get information about treatment, a short interview was held afterwards.

5.1   Orkdal Hospital

The first observation was in Orkdal Hospital. The room observed was the gym. The gym was the room in which the physical therapists thought it easiest to use the system, due to the large space available. They chose to have a TV on a trail to make it mobile, so it can be used in different rooms.

The gym has a large free area where the patient can move freely. There are several other exercising machine and instruments in the room (see Figure 5.1). This room is used by the rehabilitation patients to do exercises and strength training of their muscles. From the look of the machines and instruments present in the gym, it can be assumed that the room is primarily used to rehabilitate the larger muscle groups. There are several machines and tools, for example ergo bikes, a treadmill and several Pilates-balls for stomach and back strengthening. There are also some balance boards used to rebuild the sense of balance in patients.

Figure 5.1: The physical therapy gym in Orkdal Hospital

5.2   St. Olav University Hospital

The second observation was at the St. Olav University Hospital in the "Kvinne-Barn-Senter's" (Women and Child Center) ergo therapy room (see 5.2). This room is used by children and juveniles in completing their therapy exercises. This room was observed because it was the one the physical therapists suggested using the Wii in.

The first thing that is seen is that there are a lot of toys around. In one corner there is a PC and a TV which looks kind of like an office corner (see Figure 5.3). On the other corner, there is a coffee machine, water boiler, microwave oven, and a sink which makes it look like a mini kitchen. On the other side of the room (see Figure 5.2b) there is a doll house, a mini staircase and some other toys. You can also find two large closets with toys and other equipment (see Figure 5.4).

There are also some instruments used to measure progress, for example one that measures grip power (see Figure 5.5).

Figure 5.2: The ergo therapy room where the Nintendo Wii can be used
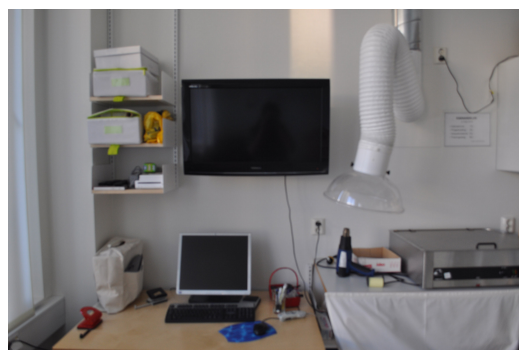
Figure 5.3: "Office Corner"

Figure 5.4: The closets with toys and equipments
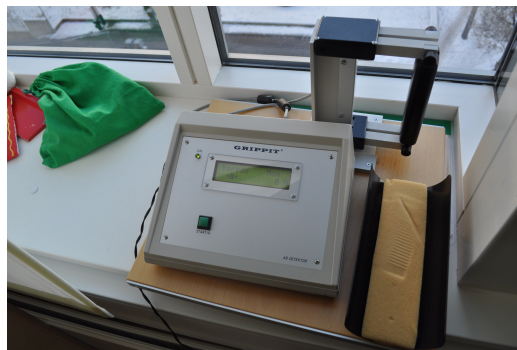
Figure 5.5: Grip power measurement tool

5.3 Summary

Observations led to the conclusion that the therapists' workspace has plentiful of different training instruments. They have mechanical instruments, medical instruments and technological instruments. There were no patients present at the observation, and thus therapists' action was not observed. Observing that the rooms were heavily equipped with various technological and non-technological equipment, introducing a Wii would not seem out of place.

It was decided that the therapists should get a firsthand experience of the Nintendo Wii platform, hence two Nintendo Wiis with several peripherals and accessories were ordered and installed in the hospitals. One was installed in St Olav's University Hospital in Trondheim, and one in Orkdal Hospital. This will let the therapists test the Nintendo Wii for themselves, and also experiment using it with their patients. The Wii systems were installed between the first and the second workshop.

Chapter 6

Workshops

This chapter is about the planning and execution of the workshops. At the end of each section, a summary will be presented.

6.1 Technology Introduction Workshop

This is the first workshop and was held as NSEP's[1] usability lab (see Figure 6.1) where we invited five physical therapists. The primary goal of this workshop is to introduce the therapists to the project and demonstrate the technology, and see if further cooperation is possible. The workshop is divided in three parts.

6.1.1 Procedure

1. Introduction of the project

2. Introduction of Nintendo Wii with the control and games, and getting familiar with the technology.

3. Discussion and brainstorming of what possibilities they see using this kind of technology in physical therapy.

---

[1]The Norwegian Electronic Health Records Research Center

Figure 6.1: Introduction workshop with testing of Nintendo Wii

Figure 6.2: ITU Video Screenshots

6.1.2 Execution

In the introduction, the participants were introduced to the Nintendo Wii, and the concept of motion sensing control. They were shown a video (see Figure 6.2) made by IT University of Copenhagen of a few newly operated orthopedic patients who used Nintendo Wii as part of their physical rehabilitation. After the introduction, we let the therapist get a firsthand experience of letting them play a couple of pre-chosen games. None of the therapists had any experience with Nintendo Wii beforehand, and most of them did not have any experience with videogaming at all. They agreed that it was a good idea to try it out first, saying:

> *"It is wise to have tried it out a bit, because you will experience it with your own body."*

The first game chosen was Tennis from Wii Sport. This is as stated in 2.5.1 the first game made for Nintendo Wii. Two of the therapist tried it, and without much introduction, they started to understand the concept of using the motion controlled Wiimote. In the beginning they experienced some problems with the timing of when to swing the control (see Figure 6.3), and they said things like:

> *"This is not easy"*
>
> *"It is harder than it looks"*
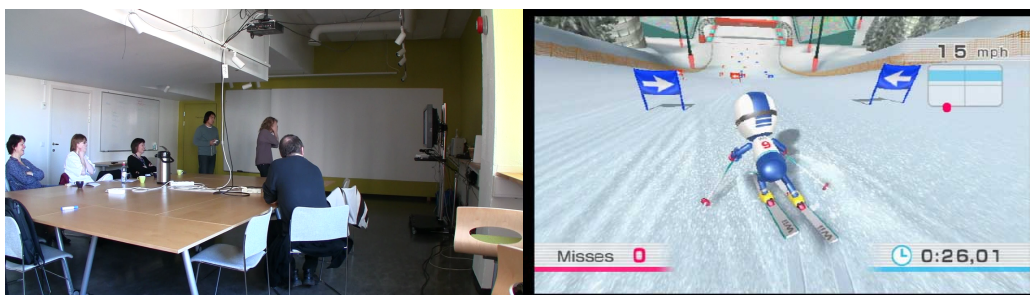
Figure 6.3: Female in the middle Playing Wii Fit Slalom for the first time

Even that they were not perfect in playing the games, the atmosphere was good, and they laughed and had fun. The therapists seemed interested. The

next thing that was introduced to them was the Wii Balance Board with the game Wii Fit Plus. A new therapist volunteered to try the game Wii Fit Table Tilt (see Figure 2.12 and 6.2)which was shown as an example in the introduction video). Before the game can be started she had to go through a registration process to make a new profile. After stepping on the board, she wondered if she had to read all the instructions on the screen, and if this had to be done every time the game started 6.4. I assured here that this is something only needed to be done once. This process took about 10 minutes, and did not seemed fed up with all the screens she had to go through before the game can be started.
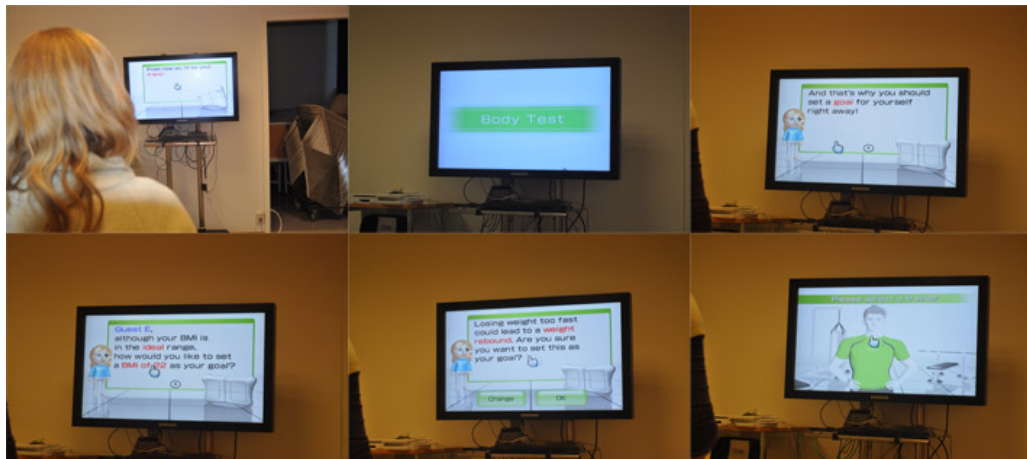
Figure 6.4: Wii Fit - menu - body test - selection screen

She understood the concept of shifting the center of balance to steer the board, and exclaimed:

> *"I promise I have not tried this before"*

This was a sign that the therapist felt comfortable on the balance board, and had a sense of control. The next volunteer therapist who was trying the game slalom did not have the same experience. She felt that the game was too fast, and she did not get much time to get familiar with the balance board.

To show the therapist a different kind of game, the squat exercise was chosen. Another therapist tried it. This game is a strength training game where the player has to do the squats with a virtual instructor. Following this, the Wii Sport Resort game, with the Wii Motion Plus extension was introduced. The

game wake boarding was demonstrated by the moderator before a therapist got to try.

Finally the therapists and moderators discussed various aspects and possibilities of using Nintendo Wii in physical rehabilitation. The therapists were asked open-ended questions about their opinions and thoughts towards various aspects of Nintendo Wii. All the therapists were very enthusiastic and excited in the discussion part, saying things like:

> *"This is very exciting!."*
>
> *"It is only imagination who can set the limit."*
>
> *"Endless possibilities!"*

The comments and response from the participants showed that they were very positive to Nintendo Wii and this type of technology. They all agreed to further cooperation and wanted to follow the proceeding of this project closely.

6.1.3 Summary

This workshop made a good foundation for further cooperation. The therapists were very positive to use Nintendo Wii in physical rehabilitation, and could see a lot of potential. They were not familiar with the console, but got a firsthand experience with it during the workshop. Of the research questions stated in Section 1.3, this workshop helped to answer RQ1 (Are existing Nintendo Wii console games suitable in physical rehabilitations usage?). Based on the therapists' comments, we can indeed see a lot of potential in using the Nintendo Wii in physical rehabilitation.

6.2 Participatory Design Workshop

This is the second workshop, and like the first workshop, five physical therapist and two facilitators were present. The goal of this workshop is to get design ideas to develop a game for physical rehabilitation. The Nintendo Wii console has been installed in their workspace, and they have gotten a few days to try it before attending the workshop.

6.2.1   Procedure

1. Introduction of today's workshop

2. Discussion around thoughts they had made after the first workshop

3. Testing a few games

4. Discussion the existent games, their pros and cons.

5. Discussion about what kind of patients is suitable, and what kind of games that would be suitable for these patients

6. Explain the designing process and the idea of 2D prototyping.

7. 2D game designing / prototyping in smaller groups

8. Presentation of the ideas

9. Plan on how to move forward with testing

6.2.2   Execution of method

The goal of this workshop was introduced to the participants, and the participants discussed thoughts they had had about the Nintendo Wii since the last workshop. The participants shared their thoughts with each other. Like last time, a couple of pre-chosen games were shown, and they all started to discuss which elements of the games were good, and which could have been better. The game used this time was a game where the player stands on the balance board, and navigates a person in a bubble along the river without hitting the shore or rocks. This game was tried in both standing and sitting position.

When they were finished discussing the games, the facilitator started to explain the next task. The task given to the participants was to design a couple of ideas for games that could be used in rehabilitation. To do this the facilitator explained the gaming design process, and what was important in the process. Two groups were formed, and they were separated into two rooms and had no contacts with each other. The participants were provided with a Wiimote, a whiteboard, and a couple of whiteboard markers, and were then asked to come up with a draft of a game in approximately 30 minutes before presenting to each other (see Figure 6.5). Group 1 had three participants

with a facilitator, and Group 2 had two participants and a facilitator. After the 30 minutes the two groups presented and discussed their ideas with each other.

Figure 6.5: Group 2 in design process
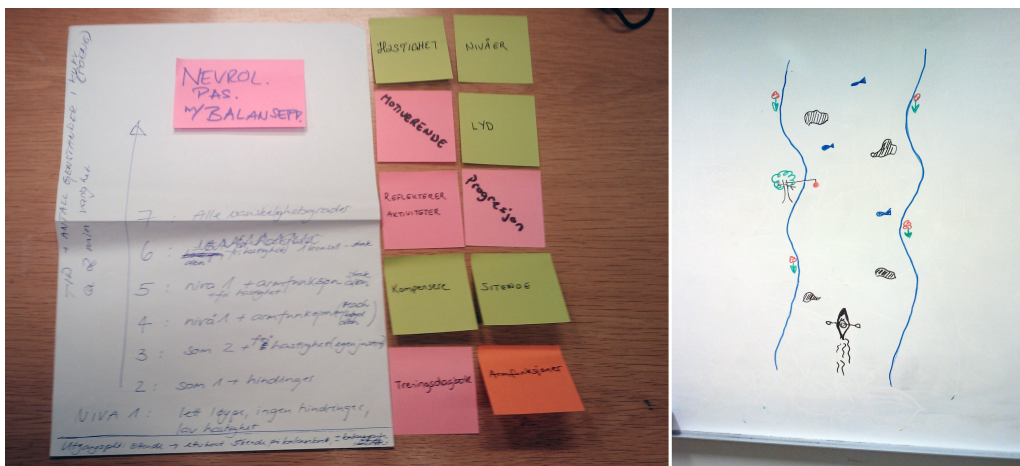
Figure 6.6: Group 1's design

6.2.3 The Groups' Design

Design 1 - River Adventure

This game is inspired by Wii Fit's Bubble River (see Figure 6.7). The gameplay is the same, but a lot of customization has been done. There are several additional gameplay elements, and a difference pace and level design which is

more suited for patients in need for physical rehabilitation (see Figure 6.6). The objective of the game is to steer a boat in a river. The player will get points for getting different items and will lose points if obstacles are hit. To get the different items in the river, the patient has to do different motions, like lift arms to pick an apple, stretch it sideways to get flowers, or move the arms downwards to get a fish. The boat is controlled with the Wii Balance Board.
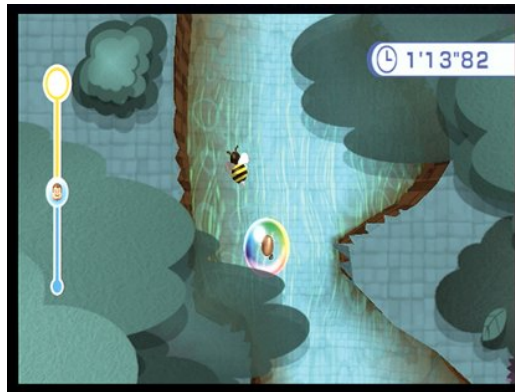
Figure 6.7: The Bubble River game in Wii Fit Plus

The game's design user group is neurological patients with balance difficulties. To suit the different patient's condition, there are designed seven different levels of difficulty.

1. Level 1: Easy path and no obstacles, low tempo

2. Level 2: Like the first level, but with obstacles

3. Level 3: Like the second level, but the tempo is controlled by the player

4. Level 4: Like the first level but with arm functions (pick up apples, flowers and fishes)

5. Level 5: Like the fourth level but the tempo is controlled by the player

6. Level 6: Like the fifth level but requires stretched elbow

7. Level 7: Faster tempo and more obstacles

The therapists decide which level the patients are going to start on. It takes about 2 minutes (or less) to go from the start to the goal, and the time and the items that are picked up determine the score. The game is designed so that it can be played either sitting or standing on the balance board.

Design 2 - Rotating Maze

Group 2 wanted to make a game in which the patient had to use their hands. Several ideas where discussed, like juggling balls, or pour water into a cup, but they ended up with a rotating maze game.

Rotating maze is a game where the user manipulates the orientation of a maze to navigate a rolling ball through it. The ball will fall because of the gravitation that will draw the ball downwards. The mazes will have several sizes and complexities. It will start with a simple one, and gets more difficult through the game. It is possible to customize the sensitivity of the rotating maze to adjust it for patients' needs.

To encourage the patient to do a favorable motion without compensation, it is decided to make a holder for the Wiimote. *Compensational motion* is one of the problems that the therapists experience with their patients. Patients often compensate for limited motion in an affected joint by moving other parts of their body, often without being aware of it. The holder should be longer than the original Wiimote, and should not be round to avoid patient moving their hands around. The patients are "masters of compensation" said one of the therapist. They are not aware that they are avoiding using their affected joint, and get by their daily activities by compensating with other parts of their body.

The game and the Wiimote holder was later developed, and it is described in Section 8.1.3 and Section 8.1.4.

6.2.4 Summary

This workshop provided many interesting opinions and ideas of what to think about when developing a game for physical rehabilitation. Some of the ideas and opinions are summarized in the following:

Difficulty

- Different levels and stages that increase in difficulty.

- The difficulty should be adjustable to fit the patients

- The speed of the game cannot be too fast

Usability

- The motion displayed on the screen should be an accurate representation of the actual physical motion being conducted.

- The game should be easy to learn without reading a lot of instructions

- The game sound should be kept simple so it does not distract the players

- The actual gameplay should be easily reachable by using simple menus and quick startups

Motivation

- Competition against oneself or other players

- Log of training

- Users will be motivated by doing practical movements they need for daily activities

- Should be relevant of an everyday activity, for example taking on a sweater, or stretch and grab something.

- Scores

- Measurable progression

- Feedback from the system

Quality of the Motion

- Using several muscle groups

- Using aids or physical restraints to ensure the desired motion, rather than allowing full freedom of movements which would allow some patients to do compensational movements.

These ideas will contribute mostly to RQ2 (What are the design challenges associated with creating systems for Nintendo Wii to be used in physical rehabilitation?) and RQ3 (Can the lessons learned in this project be synthesized to a set of design guidelines for rehabilitation games with motion control?), and also in some extent to RQ1.

6.3 The Third Workshop

The aim of the third workshop was to present a few prototypes of the games designed in the previous workshop, and to get feedback from the therapists on them. This is done to confirm that the developer has understood the therapists' ideas correctly, and to obtain feedback for use in the iterative design model presented in Figure 4.1.

The schedule of the workshop is as follows:

1. Welcome

2. Experiences obtained since the second workshop

3. Discussion

4. Presentation of Game 1: River adventure

5. Feedback of Game 1

6. Presentation of Game 2: Rotating Maze

7. Feedback of Game 2

Present at this workshop were four therapists and one facilitator. Two of the games from Workshop 2 have been developed into prototypes since the second workshop, and were presented. After the presentation of each game, the therapists were encouraged to give feedback.

6.3.1 Summary

Some of the therapists had already had the chance to test the Wii console, with existing games, in rehabilitation. They had written a small report of the experiences they had while testing on patients, and also a review of some of the games they have tried. The review table can be found in Appendix C.

One of the therapists said that:

> *"There is some favorable movements in the games, for example canoeing and fencing. Some of other games have too monotonous movement patterns."*

The movements with the hand while rowing the boat from side to side, and the movements of the arm while fencing was reported as a favorable movement by the therapists. While the therapists found that another game, cycling, used too monotonous motion to be used with their patient. The "bubble along the river" from Wii Fit Plus games (see Section 2.5.3) was tested with a stroke patient. The goal was to train the patient's sitting balance, but reportedly, the patient compensated by using the side of her body that was good and not the one she needed to be trained in.

> *"What we saw in her performance was that she was slightly over-active and compensated with the side that she was most functional in already, so she did not necessarily get the appropriate activity on the side of her body where she needed to train after the stroke"*

The therapists concluded that the patient probably should have trained more basic sitting balance before using Nintendo Wii in rehabilitation. However, the therapists claimed that this kind of training would be valuable for this patient group, but that it ideally would require games that are more suitable for the patients and a physical therapist present to avoid compensational and other inappropriate movement patterns.

The therapists said that one of the challenges in using these games is that the patients are of all ages. They suggested using daily activities in the game to make it more relevant for the patients, for example taking on a sweater or eating with a spoon.

It was reported as slightly demanding using Nintendo Wii because they had used one therapist to teach the patient how to play the game (focusing on game and patient), while a second therapist was observing and analyzing the patient to look out for compensation and inappropriate movement patterns.

The prototype was presented as screenshots in a PowerPoint presentation (see Figure 6.8). This is an early prototype to confirm that the developers mental model of the game is similar to the physical therapists'. The game design idea came from the previous workshop, and with an early prototype it is possible to obtain this confirmation that the developer's idea is actually what they meant. The screenshots were shown to them, and a discussion was initiated to find out if this is what they had in mind.

> *"This is very interesting"*

> *"... I imagined the maze to be a somehow bigger"*

> *"This game has potential to be very addictive. And can motivate the patients to do their training."*

The prototype got comments and feedback which were noted so that they could be taken into consideration and be implemented in the next prototype. An achievement system and a high score list that was to be implemented into the game in order to make this game have a higher replay value was presented. That was something the therapist said they wanted. Some achievement suggestions are:

- Completed 10, 50 and 100 levels

- Played 10, 50, and 100 times

- The ball has rolled 100, 500, and 1000 meters
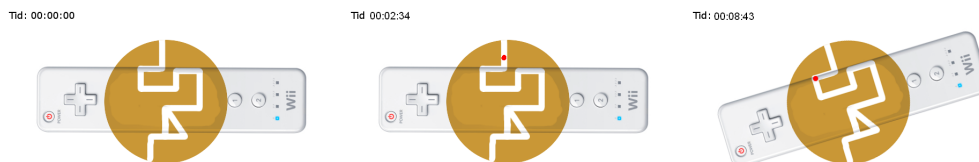
Figure 6.8: Screenshots of Rotating Maze Prototype

The second game presented was River Adventure shown in Figure 6.9. This game was one of the ideas the therapist came up with in the previous participatory design workshop. The game idea came up after they have played the Bubble game in Wii Fit, and was meant to be a customized version of that game to be used in physical rehabilitation. The feedback from the therapists was quite specific.

> *"The river should be wider"*

> *"It can be difficult for the patient to follow so many elements on the screen; maybe we should have fewer things on the screen at once"*
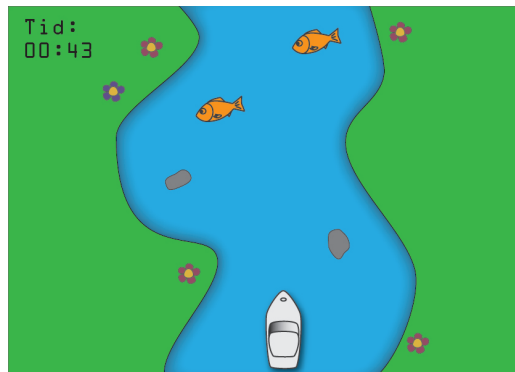
Figure 6.9: River Adventure prototype screenshot

This was some of the feedback the therapist gave when they were presented with the prototype. From the presentation and the discussion, it was observed that the main idea of this game was understood correctly, and that the therapists were excited about the idea. The feedback given by the therapist made a good basis to work with on the next iteration of the prototype.

This workshop was very interesting in the sense that the therapists got an actual prototype that they could discuss and comment on. It is easier for them to comment on something that they can see, than an unseen concept or idea, as Fallmann (2003) [16] describes:

> *"... the research prototype is typically used as a researchers' proof-of-concept as well as exposed to users to conduct evaluations"*

The first part of the workshop where the physical therapists described their experience with using Nintendo Wii on a stroke patient is related to RQ1. The training they did on the patient can be beneficial, but it requires some planning, and at least one, preferably two physical therapists to be present, assisting and instructing the patient in the proper movements. The second part with the evaluation of the prototype is helping to answer RQ3. The game should have some elements that can motivate the patient to play it several times. Also, the game should have adjustable (but often low) difficulty so that it will suit the patient, a relatively short timespan, and a minimum of distracting elements because of the concentration problems experienced particularly by stroke patients.

Chapter 7

Interviews

This chapter describes the interviews conducted in the project. The interviews were conducted with therapists from St. Olav St. Olav University Hospital in Trondheim. The interviews are about the therapists' experience with using Nintendo Wii in physical rehabilitation. The purpose of the interviews' was to see what kind of challenges the therapists had experienced when using Nintendo Wii in physical rehabilitation.

7.1   Interview 1

Do you have any examples of using Nintendo Wii in your clinic? The therapist told about a teenage patient who had experienced a car accident resulting in reduced functionality in his right hand and balance. It has been conducted a couple of surgeries to help him regain his functionality, but his right hand was still very immobile, and he had problems with twisting his arm and gripping objects. The patient had always been left-handed. He was familiar with the Nintendo Wii console, and had been playing it at home for about a year.

Which software was used? Several Nintendo Wii games were used to test if the patient was capable to use and understand the Nintendo Wii. The games used were Wii Sport Boxing, Tennis, and a few Wii Fit games. The therapists did not observe any problem with navigating through the menu. They explained that the patient in prior was familiar with the Nintendo Wii system and the games, and only used his dominant left hand to point and

click through the menus.

What was the challenges using Nintendo Wii in physical rehabilitation? The therapists stated that the patient mentioned in the last questions, had some difficulty with using his right hand. When playing boxing he used an elastic band to keep the Nunchuck (described in Section 2.2) in his right hand. He used mostly his dominant hand to jab the opponent, and occasionally his right hand to do an uppercut or hook. It was clear that he was much more comfortable using his left hand than his right. The patient was very energetic and motivated when he played Nintendo Wii, and got tired with only a few minutes of playing. He was breathless and perspired, and needed to take a small break before playing the next game.

When playing Wii Sport Tennis with his right hand, he needed aid with a strap to hold the Wiimote in his hand. It was very hard for the patient to hit the ball with the right timing although he had no problem with hitting it with his dominant hand. He was very focused but experienced difficulty to play this game. After a couple of tries the patient moved on to the next game, Wii Fit Plus.

Wii Fit Plus (see Section 2.5.3) uses a balance board to play the game by measuring the player's center of gravity, and the Wiimote to navigate through menus and also to control hand motions of the player. Three games were tried in Wii Fit Plus, the Balance Bubble, Driving Range (Golf), Segway Circuit. The therapists explained that the patient had an injury in the the lower body, and he needed help from the therapist to get on the balance board. Once on the board he could hold his own balance on the board, but he stood on the toes on his right foot. This was his neutral position.

The therapist further told that the patient had never played these games before, and seemed very excited to try it. The Balance bubble uses the balance board's center of gravity to determine direction and pace through a river with obstacles. He did not use a lot time to grasp the concept of changing his center of gravity to move the bubble through the river, but he had to be very concentrated, and after a few tries, he got better and did not seem to have much problem with this game.

The second game the patient tried was Segway Circuit. This game used the balance board to accelerate and brake with the balance board, and used the Wiimote to turn left and right. The therapist observed that the patient held the steering wheel 90 degree wrong, and led to the segway turning right. Figure 7.2 is my reconstruction based on what the therapist said. The patient

could try to steer straight, but because of his wrong handling of the steering wheel, it was impossible for him to turn left. Even after some practice, he was still unable to hold the steering wheel comfortably correctly. The therapists did not observe any problems with the controlling of the accelerating and the breaking on the balance board.

Figure 7.1: Illustrational photo of patient playing Segway Circuit
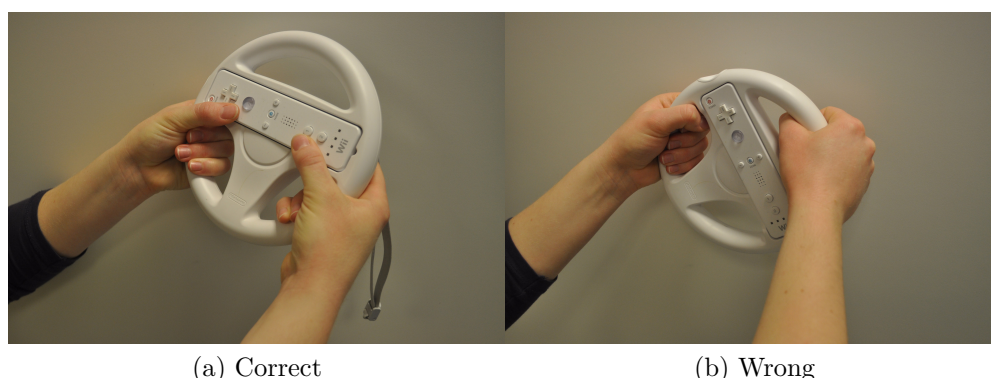
(a) Correct   (b) Wrong

Figure 7.2: Illustrational photo of holding the Nintendo Wii Steering Wheel from NSEP

Driving Range is a game that uses the balance board and the Wiimote to play golf. The player had to shift his center of balance and coordinate this movement with an arm swing to get a good result. The therapists explain that the patient with a couple of times of practice did not seem to have problem with playing the game, and had fun while playing.

Did the patients enjoy playing Nintendo Wii? The therapist observed that the patient really enjoyed playing the Wii. He managed to do motions

that he usually struggles to perform without thinking about it. And the patient exclaimed that "This is hilarious and fun!". The session was a very fun experience for the patient, and he and his mom both agreed that they would go out and buy Wii Fit Plus with balance board right away. The therapist was positive that this will help the patient with his rehabilitation, but the therapists recommended that the patient continues to do his ordinary exercises. The therapist suggested that the patient kept playing Nintendo Wii, not as part of his rehabilitation training, but as a leisure activity in his spare time.

7.2   Interview 2

This field evaluation was carried out as the St. Olav University Hospital in Trondheim.

Do you have any examples of using Nintendo Wii in your clinic? The patient was a child with a right hemiplegia disorder. Hemiplegia is a condition affecting one side of the body. It is caused by damage to some parts of the brain, which may happen before, during or soon after birth [27].

Which software was used? Several games were tested during the session, including Wii Sport Tennis, Wii Sport Resort Sword Play, Wii Sport Resort Canoeing, Wii Sport Resort Table Tennis, Wii Fit Plus Slalom and Soccer Heading.

What was the challenges using Nintendo Wii in physical rehabilitation? During the session, it became clear that patient had good functionality in his left hand thus he chose to use only his left hand if the activity allowed it. His right hand had a relatively good grip function, but was quite weakened. He tended to volar flexion in the wrist. He was spastic in his elbow and therefore often had a flexed elbow position despite the fact that he could stretch out the elbow on request.

It was observed that the boy could keep the Wiimote with both hands on request from the therapist. However it was the left hand that largely controlled the movement, and the right hand was only "there" to follow.

The patient had a tendency to have an asymmetric use of the body, where the left side is leading, while the right side was more withdrawn. When he was leaning forward on the balance board, he had a tendency to pop up on

Figure 7.3: Reconstructed photo of the patient's feet

his toes with his right foot. Reconstructed photo in Figure 7.3.

However, if the Wiimote accessory was designed in a different way, it could stimulate his training more. It would have been an advantage if the games demand or captures how the arms are used to stimulate the most "correct" use of the body.

It was observed that several of the games could have been implemented in other ways to get the patient to do a more desirable motion in relation to the symmetrical use of the body. The games that required the use of steering wheel required twisting of the forearm, which sometimes worked well.

Did the patients had fun while playing Nintendo Wii? The patient had a lot of fun while playing, and although he had difficulty with some of the games, it could be assumed that with more training he would become familiarized and succeed in playing them too. It was hard for a six year old to understand all of the games when he could not understand the English instructions on the screen. Even though he was told what to do he was quite stubborn and tended to do whatever he desired, in a normal, playful childish way.

It was observed that he had a good time when playing multiplayer games with his father. This social aspect can contribute to make him more motivated to play Nintendo Wii games.

The therapists concluded that the exercising using Nintendo Wii systems can motivate the patients more, compared to performing traditional exercises.

Chapter 8

Prototype and Evaluation

This chapter is about the prototypes and the evaluation of the prototype in this project. Section 8.1 presents the prototypes designed in this project, and Section 8.2 outlines the evaluation of the prototype conducted at the end of the project.

8.1 Prototype

8.1.1 Wiibrew

There are very few options for customizing the Nintendo Wii console without buying the expensive official Game Development kit. The kit is intended for use by professional game development companies only, and has very strict requirements on how the kit should be used and where to be stored. In addition, there are very few software tools available to assist development [33].

Wiibrew is an online community that shares information about how to make unofficial software created for Nintendo Wii by its users, without the involvement of Nintendo. Software developed in this process is called *homebrew*. Nintendo disapproves and makes efforts to prevent this, due to the potential for unofficial software to brick the system or to be used for piracy. Making unofficial software for Nintendo Wii is not illegal, although it is against Nintendo's license agreement and might void the warranty of the Wii. For

research purposes though, this project will still try to make homebrew applications that can be run on Wii to explore its potential to be used in physical rehabilitation.

To run homebrew applications, you have to run an exploit of the system. There are several known exploits such as the Bannerbomb [57], the Twilight Hack [58] or the Indiana Pwnsx [56]. These are exploits of a fault in the system.

One of the easiest ways to run homebrew applications on Nintendo Wii is to install the Homebrew Channel [55]. The Homebrew Channel is a homebrew application loader which allows users to load homebrew applications without having to run an exploit every time.

To develop for Wii the devkitPPC [47] is used. devkitPPC is a part of the GNU Compiler Collection and includes a C and a C++ compiler. It is designed to be used in conjunction with libogc, a collection of Wii-specific low-level libraries. An example of devkitPPC code can be found in Appendix A. Although it is possible to make simple games with this approach, it will still be hard to make a working prototype, since it is not well documented, and some libraries and tools are missing.

8.1.2   GlovePIE

GlovePIE is a free Programmable Input Emulator which supports a range of input devices, such as the Wiimote with Wii Motion Plus. This can be used on a Windows PC with Bluetooth, and it can pair up the two devices easily. With this we can make application that uses the Wiimote with Wii Motion Plus in Windows platform and the Java development environment. The code can be found in Appendix B.

8.1.3   Rotating Maze

Rotating Maze is one of the games which the therapist came up with in workshop 2 (described in Section 6.2, see Figure 8.1). The objective of this game is to move the maze to navigate a ball through it. The ball will fall because of the logical modeled gravitation that will draw the ball downwards. The mazes difference in size and complexity. It will start with a simple one, and gets more difficult through the game. It is possible to customize the
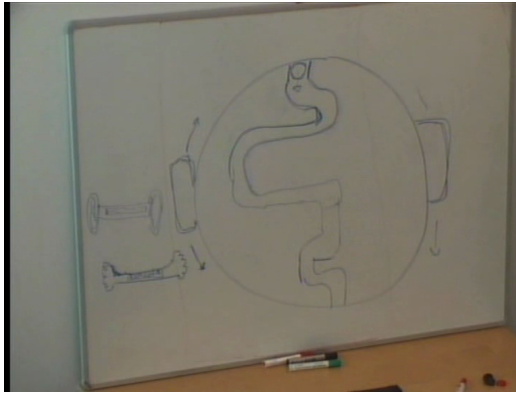
(a) Rotating Maze design

(b) Rotating Maze prototype

Figure 8.1: Rotating Maze from design to prototype

sensitivity of the rotating maze to adjust it for the patient's needs. This game can either be played with a Wiimote that has a Wii Motion Plus attached or with a Wii Balance Board. With a Wiimote it can either be played with one or two hands. With one hand, the players will hold the Wiimote as with a TV remote control, and with two hand, as a steering wheel. It is possible to use different holds.

This game is used with a custom made add-on to the controller to help the patients have a better grip, for a better rehabilitation result.

8.1.4   Steering Wheel Prototype

Many patients have problems holding the Wiimote and using the buttons [1]. It is important that the games are valuable from a therapeutic perspective, and therefor is it important to make Wiimote accessories that are suited for the games designed. From the workshops and interviews, it is observed that the accessories are indeed very important, but the off the shell Wii steering wheel was not ideal in physical rehabilitation. They are made with a healthy person as the user in mind, and do not take into account that some patients will have problems to use it, like some of the therapists had observed(7).

A prototype of the Wiimote holder was made (see Figure 8.2), and is based on the specifications the therapists gave in the participatory design workshop (Section 6.2). The prototype is a bit longer than ordinary Wiimote steering wheels, and is not circular. This is made so that the patients are required to use a bigger muscle group, and to ensure that they don't perform compensative motion. Patients often compensate for limited motion in an affected joint by moving other parts of their body, and with this design, it will be more difficult for the patients to compensate.

Another advantage is that the prototype can be used in combination with a flexion glove for patients that have difficulties holding the Wiimote.

The drawbacks of this design is that the buttons of the Wiimote are not reachable when holding the prototype, but as described by the therapists during the participatory design workshop, only a small group of the patients are able to use their hands to press the buttons while holding a wheel. The games designed for use with this prototype should be played button free.

(a) Steering Wheel prototype front   (b) Steering Wheel prototype back

Figure 8.2: Prototype of the steering wheel

8.2 Evaluation of Prototype

The prototype was evaluated in a meeting with the physical therapists. The purpose of this meeting was to evaluate the prototype and discuss various challenges with using Nintendo Wii in physical rehabilitation. Only two of the five therapists which attended on the previous workshop attended this time. The meeting was divided into two parts. The first part is a semi-structured interview between the researcher and the two therapists. The second part, where the prototype was presented, allowed the therapists to give their feedback.

The therapists had a lot of good ideas about game developing for patients. One of the great challenges was how one can develop a game that can suit different kind of patients in different phases. They described a patient who recently had stroke who they tested out Wii Fit on. The patient had problem with balance and standing up. They tried to use Wii Fit Plus in the patients training. The game used was the one that resembles the River Adventure game, where the patient controlled a bubble with change of center of gravity to steer the bubble. The game was perceived as too fast for the patient, and the patient had to try again many times. The therapists said that the patients in this phase of their rehabilitation needs mapping of the affected areas. This phase might not be the best time to introduce new technology.

Patients who recently have had a stroke usually have difficulty with their concentration, and will get easily distracted. To introduce them to Nintendo Wii if they have not been playing it before might be a challenge. Some stroke patients have also been affected cognitively, and may not be able to understand using motion controlled devices to control something in virtual reality at all. For this kind of patient, in this phase, the therapists suggested another training method that can identify and map the patient's problems. If games are to be developed for these patients, it has to be extremely simple and have very few distracting elements.

The usefulness of Nintendo Wii will be very dependable of what kind of patient it is. The therapists suggested that an orthopedic patient might be a better patient to try Wii on because they are not affected cognitively, and can use Nintendo Wii in a much earlier phase compared to a patient who has recently had stroke.

Another challenge using Nintendo Wii with some patient is that they have different grade and form of disabilities. Some might not be able to control

their movements, while other cannot perform the motions needed.

One of the greatest challenges for physical therapists is to get the patients to follow through with their rehabilitation at home. The therapists explained that the exercise cannot be boring or painful, and the effect should come quickly so that the patient does not lose interest and stop doing their rehabilitation at home. The advantages of using Nintendo Wii in physical rehabilitation are that it can give immediate feedback to the patient and that it does not take much space. It is also cheap, and can be played both by a healthy person or other patients. This is one of the activities that the patient's family can take part in with the patient which might encourage them to do more of the rehabilitation at home.

Another advantage is that since Nintendo is the most selling video gaming console at all time, a lot of families already have it at home. The parents can play with their children and they can bond through playing games together. The Nintendo Wii with customizations might also be able to keep a training log that can work both as a motivational factor and as a control so that the therapists can see how much the patient has been training.

For the Nintendo Wii to be used in physical rehabilitation it has to be easily available to the patients. The therapists explained that if a device is hidden or needs to be installed by a therapists every time, it will probably never be used. It is also important that it can be used at once, if the patient have to wait several minutes for it to activate, the patients will probably lose interests.

One of the great challenges that the therapists mentioned was how one can develop a game that can suit different kind of patients in different phases. The game has to be customizable. Just as a normal video game that usually starts with a tutorial phase, and then increase in difficulty, a game for physical rehabilitation has to be the same. The easy part has to be very simplistic and easy, before the difficulty can be increased slowly. To fit different kind of patients the difficulty, speed, graphics, sounds, and the controller's sensitivity all have to be adjustable. Even the method of control input should be adjustable. The games should be able to be played with one hand, two hands, and maybe with a balance board. Different accessories can be attached to the Wiimote for a different training effect.

The game must be motivating, and therefore it cannot be too easy or too hard. If the game is too easy, the patient will either lose interest or it will not have the desired training effect. If the game is too hard, and the patient keep

losing, the patient will be frustrated and demotivated and might give up. As one of the therapists said: "Variation and feedback is alpha and omega".

The Nintendo video games as they are today have limited usage in physical rehabilitation. The games are developed with the thought that the player will have fun, and not with rehabilitation in mind. Even the fitness games are made with fun as the first priority, and weight loss as second. They are all designed for healthy people, and not patients who need physical rehabilitation. Most of the games are too hard, and impossible for many patients to use. Some commercial games have elements that should not have been included in a rehabilitation software. For example, the focus on BMI (Body Mass Index) in Wii Fit, and that it takes approximate ten minutes just to register a player (see Figure 6.4). The game also gives negative comments, such as "This is obviously not your cup of tea, do you find yourself tripping often when you walk". Comments like that is probably meant as humor in the game, but are most likely not something a patient who has problems with motions wants to hear.

There is 100s of different Wii accessories in the market (examples on Figure 8.3. Most of them are made just to put the Wiimote in to make it feel more like the thing it mimics. For example a Tennis racket, a Baseball bat, a sword, or a pistol (see Figure 8.3a).

| (a) Wii accessory set | (b) Friiboard | (c) Wii Weight accessories | (d) Wii Vitality Sensor |
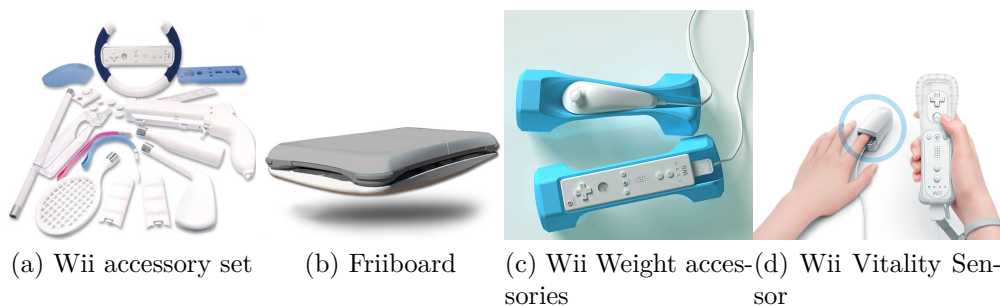
Figure 8.3: Some Nintendo Wii accessories

To make and use the appropriate accessories is also an aspect that must be thought of when designing for Nintendo Wii. A lot of the patients that need to train their hands, arms, or wrists are not able to grip the Wii remote or use the buttons. Even if their motor skills are good enough to use the buttons, it might be too much for a patient to use the buttons while focusing on the screen. Focusing on several things at once is often hard for patients who have experienced a stroke, CP or other kinds of head injury.

If the patient is using a wrong hold on the Wiimote, it might lead the patient to use a not desirable motion which could even lead to a strain injury or, more normally, reduced training effect. By making the handle bigger we get several advantages. Firstly the motion needed is larger which can lead to a better motion outcome, and secondly it will be harder for the patient to make compensational motion. Figure 8.4 shows the therapists trying the Wii handle prototype with the rotating maze prototype in different initial positions of the arms.

(a) Stretched arms   (b) Closed position

Figure 8.4: A physical therapists evaluating the prototypes

The customized handle should be adjustable for different patient needs, and should be used in combination with flexion gloves for the patients who have problems holding the Wiimote.

The quality of the motion is very important in physical rehabilitation. In a video game for fun, the player is offered to choose between doing the motion large and hard, or small and quick. Games that are used in physical rehabilitation should require and encourage use of accurate favorable motion. The movement patterns should have a high degree of variation. Too much of the same movement pattern over a period of time might lead to secondary motion problems for the patient. It is also important that the motion is accurate to what the therapist suggested and that the patient is not compensating, for example instead of using the arm to lift something, the patient can use their shoulders. The physical rehabilitation game should make the patient want to do the optimal motion of choice, and identify when the patient is compensating and give appropriate feedback. Too much compensation is usually not very energy effective, and this is one of the reasons why some patients gets tired faster than healthy people.

The prototype made was described in Section (8.1.3). The prototype is made in Java for the graphics and steering, while using glovePIE to connect the Wiimote to a PC. After presenting the prototype to the therapists, they had mixed opinions. They liked the potential of the maze game. This kind of game can be addictive and the patients will have much fun while playing, but they felt that the steering of the maze did not feel right, and might be too responsive for some of the patients. It can be very hard for some patients to follow the ball, while the maze is rotating. They suggested making the maze static, and that the player only moved the ball instead. Several other ideas also emerged during the evaluation, such as: There should be an option to control the ball with either one hand, two hands or with the balance board. The start position of the patient can be instructed by the therapist during training. How fast the ball moved and the sensitivity of the control should be adjustable. The elements in the game should be simple and few. There should be several different sizes and difficulties of the maze so that the patient or the therapist can choose to make it suitable for the patient to play with.

Chapter 9

Discussion

In this chapter we revisit the research questions posed at the beginning of the project in Section 1.3 and summarize the answers based on the insight gained throughout the project. The chapters my answers are based on are written in brackets.

9.1 Research Question 1

The first research question RQ1, posed in Section 1.3, asked:

> Are existing Nintendo Wii console games suitable in physical rehabilitations usage?

9.1.1 Physical space

Through the observations and workshops, I saw that the physical therapists are open minded toward new technology and methods of treatment (5.1, 5.2). They are used to perform a wide variety of different treatments to rehabilitate their patients. There are already a lot of different instruments in their daily work. All that is needed is the Nintendo Wii console, the software (games), some Nintendo Wii accessories, a TV or projector, and sufficient space to place this equipment so that it can be available for the patients. Space can be an issue, and although the Nintendo Wii console is small, it

still requires adequate space with all its accessories, but luckily, a TV or projector is usually already installed. In one of the conversations with the therapists, one of them told a story about an instrument that no one wanted because it took about 2 square meters. The physical space is an issue that the physical therapists experience in their daily work.

9.1.2   Success criteria

There are some success criteria for using existing Nintendo Wii games in physical rehabilitation (8.2). It has to be usable, meaning that is has to be approved by the physical therapists. The game has to be valuable from a therapeutic perspective, it has to be available for the patients, and the patients have to be able to use it, and more importantly, they have to desire to use it.

9.1.3   Drawbacks with existing games

There are some issues using the existing games; the main issue is that the games are designed for healthy people, where fun is the most important element in the game. The existing games might be paced way too high (6.1, 6.3, 7.1, 8.2) and have too many distracting elements for patients with cognitive disabilities (6.3, 7.1, 8.2). For some patients it might be hard to hold the Wiimote (7.1, 8.2), and use the buttons (7.1, 8.2). To overcome this problem, one can use different aids to help. For example one can use a flexion glove or a strap to help patients hold the Wiimote in place (7.1). The quality of movements can also be an issue (6.2, 8.2). Some of the existing games do not distinguish if a movement is done hard and large, or quick and small (8.2). It is also not able to see how the patient is actually doing the motion, and therefore always will need a therapist present to instruct when in use (6.2, 6.3, 7.1). There are games with favorable movement patterns (6.2, 6.3, 8.2), that use several large muscle groups at once (6.2).

The existing games usually have a lot of menus, instructions and warning screens before the game itself is started. This kind of screens prevents the patient from using the game, and is an annoyance (6.1, 8.2). The game should start quickly without much too many instructions (6.2).

9.1.4 Motivational factor

The motivation factor is important, and it has to be high for the patient to actual want to play the game. There are some games that can be played with several people, to let patients play with other patients, families or friends, which can make it competitive and fun (7.1, 8.2).

The progress is saved, and this can motivate the patients to play more (6.2, 8.2). Progress that is reinforced by visual evidence provides an additional incentive for patients to push themselves during therapy. The feedback the game gives is very important, and can be a very good motivational factor for the patient (6.1, 6.2, 8.2).

There are a lot of variation between the games on the marked that can be chosen (6.1, 8.2), which will make it fun. The games for balance exercises is well made from a physical therapists point of view (6.1, 6.2). One can use the balance board in several postures, even sitting or kneeling (6.2).

Some of the existing games are easy to understand because their motion controlling is good. The response from the screen is good enough to help the player understand the concept (6.1, 6.2, 7.1). There are already a lot of Nintendo Wii accessories that can be chosen (6.2, 7.1, 8.2) and use of these can help to encourage the patient to do more favorable movements, and also let them understand the game more easily.

From all of the activities that have been done, from the first workshop to the last evaluation workshop, it is observed that the word fun is used very often. Both the therapists and the patients think this exercising with video games is very fun. This is a factor that the existing games has, and is probably what makes them worth to play even with all the issues that is mentioned.

9.1.5 Not for all patient groups

In what degree Nintendo Wii can be used in physical therapy is very patient dependent. The patients need to have full range of motion and cognitive functionality to be able to play the games. These games might be promising for patients in the later stages of recovery. The therapists suggested at least one therapist present during the exercise to instruct and make sure that the patients are "playing" the games right (6.3).

9.2   Research Question 2

Research question 2 asked:

> What are the design challenges associated with creating systems
> for Nintendo Wii to be used in physical rehabilitation?

9.2.1   Software Development Tools

During the system development process, there has been some difficulty to implement the design solution. It is very hard to obtain the official game developer kit to Wii by Nintendo. The kit is very expensive and is only sold to professional game developer companies (8.1). Using the homebrew community to implement games to the Wii does work, but is much harder, because not all the necessary tools are available (8.1).

To use the motion controller input device from Nintendo with a PC does work, and is possibly easier, but it will be harder to install compared to developing directly for the Nintendo Wii console. It will not work out-of-the-box anymore, but need several other drivers and software to be installed to work. The experience will not be as seamless as with using the Nintendo Wii console (8.1).

9.2.2   Fun

One of the greatest benefits using video game for physical rehabilitation compared to traditional rehabilitation is that it can be more variation and more fun. Just as with the existing video games in the marked, it has to be fun, or else no one wants to play it. Crawford ([9]) believes that games provide entertainment through escape, and games are superior to other means of escape because they are participatory. In order to create immersion in an interactive environment we must make the user actually forget they are participating through a medium ([18]). Therefore the game user interface are considered best if invisible or at least unnoticed by the player ([46]).

9.2.3 Motivation

The patient that needs rehabilitation is in a hard time of their life. They might just have been through an accident or a surgery, and their body is not working as it should (8.2). It is hard to encourage and motivate these patients to do the necessary training they need, and it cannot be boring or painful, and the patients has to see the result of the training or will lose interest (8.2).

Fun relates to much more than just the user interface of the game, it also relates to the game play. Federoff found in her study ([18]) that challenge and the opportunity to master a skill seems to provide sufficient motivation for people to engage in game. This also applies for a game used in physical rehabilitation.

9.2.4 Gameplay

Physical rehabilitation games should provide enough challenge, both to keep the players interest in playing further, but also that it should get harder in term of physical motion so that the patient gets a greater effect (6.2). It is very difficult do design a system that can give challenges to all the different kinds of patients.

9.2.5 Quality of motion

The greatest challenge of designing a game for physical rehabilitation is that all the patients who are going to play the game are very different (7.1, 7.2, 8.2). The patients are all in different conditions. They are of different age, experience, motor skills, cognitive skills and training needs (7.1, 7.2, 6.3, 8.2).

Unlike users of typical commercial motion based games, our user base has specific and restricted ranges of motion. In addition, therapists want the patients to user their entire range of motion and sometimes to extend it (6.2, 7.1, 7.2, 8.2).

Compensation is one of the problems that the therapists experience with their patient (6.2, 6.3, 7.1, 7.2, 8.1, 8.2). The patient often compensate for limited motion in an affected joint by moving other parts of the body, often without being aware of it.

The system has to be able to recognize the patients' movements, and give accurate feedback to them. The system developed has to be able to discern the movement in order to make sure that the patient is actually doing the favorable motion, and not one that is harmful for the patients (6.2, 6.3, 7.1, 7.2, 8.1, 8.2).

9.3 Research Question 3

Research question 3 asked:

> Can the lessons learned in this project be synthesized to a set of design guidelines for rehabilitation games with motion control?

The experience from this project is synthesized to a set of guidelines for developers making rehabilitation games with motion controllers, these guidelines are rooted in, but not based entirely on the results. These guidelines describe issues that are especially important to remember when designing rehabilitation systems with motion control.

9.3.1 Interface

Customizable control
The patients got different disabilities, and therefore it is necessary to provide customizable control. The different patient groups needed to train different muscles, and some patient might have problem to hold the controller, or press buttons (6.3, 7.1, 7.2, 8.2).

Minimize the menu layers
The patients do not want to spend time using on the menu, when they actually want to exercise through playing (6.1, 8.2).

Use simple sound effects
Sound use is very important; they should not be overused, because some of the patients might get easily distracted of the sound (6.2, 8.2). There should also be options to turn this off.

Avoid onscreen instructions
The therapists might read the manual, but not all the patients are able to

read. Some patient might have difficulties to focus if the text is too long, or understand the text if it is complex (7.1, 7.2, 8.2).

Use simple and few graphical elements
The graphic should be simple, and not put many distracting elements on the screen (8.2).

9.3.2 Mechanics

Use natural movement
They game mechanics should feed natural, and match the actual movement on screen (6.2). For example, trying to walk in the game, with balance shifting on the balance board without lifting the legs does not work.

Have consistent and instant response to player's action
The response of player's input has to be consistent and instant so the player understands how the game mechanic works.

9.3.3 Gameplay

Involve the patient in the game immediately
The patient has to get involved quickly and easily so that they do not lose interest (8.2).

Make game difficulty adjustable
Because the game should be played by different patient groups with different age, and in different phases, it is important that the difficulty is adjustable so all the patient can play the game, and also variable so they don't lose interest. The game should be easy to learn and hard to master (6.1, 6.2, 6.3, 7.1, 7.2, 8.2).

Make game speed adjustable
The pace should be adjustable, to fit the players (6.1, 6.2, 6.3, 8.2).

Make the game replayable
The patients are going to play these game many times, and it is important that the game have a replay value (6.2, 6.3, 8.2).

Make variation in the games
Doing physical therapy can be quite monotonous, and the game should have

several variation to make it more fun (8.2).

Give rewards
The game should give rewards to further encourage the patient to play the game. The reward can for example be scores or trophies (6.2).

Give feedback
It is very important to give patient proper feedback to encourage them if they are doing it right (6.2, 8.2), and notify them if they are doing it wrong.

9.4   Comparison to Related Research

9.4.1   Research Question 1, comparison to Related Research

The findings presented in Section 9.1; using commercially available Nintendo Wii games in physical rehabilitation are very similar to what researchers have described in [1], [13], and [3]. As in this study, the conclusions are that existing Wii games can be suitable for some patients in physical rehabilitation, although they are far from being ideal. The success criteria that are addressed in 9.1.2 agrees with existing research. Decker et al. stated in [13] that games always assume a certain level of cognitive ability which may be an issue for some types of patients as discussed in Section 9.1.3. Both [13] and [1] suggested, similar to the suggestion in this study 9.1.3, to develop games for patients with weak hands and lack of finger dexterity. The importance of having a therapist present to prevent compensational movements discussed in this study is similar to the discussion found in Alankus et al. [1] who also suggests a more technical solution. The social aspect of multiplayer therapeutic games, found in this study to improve patients' motivation, is similar to the findings in [1] and [3]. The aspects of feedback and progress monitoring were found to be important motivational factors in this study, discussed in Section 9.1.4. This agrees significantly with the findings in [3].

In addition to strengthening the existing research on this research question (RQ1) by verifying its validity in the Norwegian health care system, this study goes more in depth in studying the actual environment in which these Wii-based rehabilitation platforms would be used. The challenges of available free space in the Norwegian hospitals and the need for a Wii system to be very quickly accessible is discussed in Sections 9.1.1.

9.4.2 Research Question 2, comparison to Related Research

The challenges with creating systems for Nintendo Wii to be used in physical rehabilitation discovered in this study are largely in agreement with the related research. The researchers in this field are developing PC systems that use the Nintendo Wii's peripherals. This project explored potential of developing for the Nintendo Wii, but experienced difficulties because of Nintendo's policy of not selling the game developing kit to non-professional game developers. Section 9.2.2 and 9.2.3 describes the importance of making a system that is fun and motivating, which are in accordance with the previous research. Section 9.2.4 discussed the issue of making a game that is challenging for the patient, which [1], [13], and [3] also have stated. Section 9.2.5 describes the challenge of making a system that can suit all the patients with different diagnoses, which is one of the goals of this project. This differs from previous research which limit their user group to only one kind of patients, for example stroke patients, or patients with wrist injuries. 9.2.5 further presents how therapists strive to encourage patients to use their full range of motion when exercising, which is also discussed in [13]. The problem that the patients use compensational motion in their daily life and during rehabilitation exercise is also stated in [1].

9.4.3 Research Question 3, comparison to Related Research

Some of the related research directly or indirectly mentions aspects that are important to consider when developing rehabilitating games which were also discovered in this study. For example that the games should support multiple methods of user input, to have adequate auditory and visual feedback, have a direct and natural motion mapping, detecting compensatory motion, give appropriate feedback and make game elements and difficulty adjustable.

In additional to these findings, my thesis suggest to minimize the menu layers, avoid on-screen instructions, to have a consistent and instant response to player's action, involve the patient in the game immediately, give rewards, record progress and that games should be varied enough that the exercise of a certain motion does not become boring, as discussed in Section 9.3.

This study attempts to create a more complete and concise set of guidelines

that can aid the successful development of games that more ideally aid physical therapists in the rehabilitation of their patients. This sort of list is not found in the related research, and it includes both the unique findings of this study, and the findings that agree with other studies.

9.5   Reflection on Research Methods

The following sections will discuss the research methods in this project, and in what extent they answered the different research questions.

9.5.1   Analyzing the Research Methods

Most of the techniques we used in this thesis are adaptations of research methods from the social sciences, e.g. workshops, observations, interviews, field studies, and focus groups. Their quality can therefore be assessed with the same criteria as those used to evaluate social science research. Most authors agree on basic evaluation criteria such as objectivity, reliability, validity, and transferability.

Objectivity: The researcher has been directly involved in the different activities, either as a facilitator, an observer, a developer or an interviewer. It is unfortunately impossible to eliminate all the unintended influence of the object of study. Even seemingly neutral questions affect the focus of the participants and signals what the "correct" approach is.

Reliability and Validity: The project only lasted for a couple of months, and we can't be sure that the participants in the project will give the same answers in a later period of time. Several research methods were used to triangulate the information gathered.

Triangulation in research is when one searches the same information from different research methods. The result from the different activities in the project can be used to see if it is in accordance with each other.

The results are based on data from a small set of participants, and may have affected the validity. The objects of study are all women, and are all working in hospitals. The scope and size of this research project is too limited to have validity outside the hospital setting. Similar studies should therefore be

conducted again in this setting and in other settings or with other systems to see if the user metaphors are universal or only specific for the particular case. The research questions might have gotten a different answer if other physical therapists from other work places were chosen to be the objects of study.

Transferability: Transferability concerns whether the study can be generalized to other contexts. The results from the qualitative analysis are only valid for this case. The results should not be generalized to other contexts without careful considerations.

9.5.2 Research Question Overview

Research question in Section 1.3 is found on the basis of results from the selected research methods. To get a clear overview of the extent to which methods have informed the findings of the research questions, I have chosen to grade them as shown below:

- Very important (+++) - Has informed this RQ to a high degree

- Important (++) - Has informed this RQ to some degree

- Less important (+) - Has informed this RQ to low degree

- Nothing (0) - Has not informed this RQ significantly

Methods	RQ1	RQ2	RQ 3
Technology Introduction Workshop (Section 6.1)	+++	+	+
Prototype (Chapter 8)	0	+++	++
Observation (Chapter 5)	++	0	0
Design Workshops (Section 6.2)	+++	+++	+++
Interviews (Chapter 7)	+++	++	++
Evaluation of Prototype (Section 8.2)	+++	+++	+++

Table 9.1: Methods and Research Questions

Table 9.1 gives an overview of the methods that have helped to give the answers to research questions. The first workshop helped to give direction of the research. The Prototype included all the iterations of the prototyping process, and helped to find answer to RQ2 and RQ3. The observation includes

both the observation conducted in the field, and gave insight of how the therapist worked. The design workshops were an important part to discuss and design of games, and were one of the main sources for RQ2 and RQ3. The interviews gave a lot of information about how the therapist worked with the patients using Nintendo Wii. The last evaluation of prototype answered in some degree all three of the research questions.

Chapter 10

Conclusion and Further Work

The conclusion drawn, based on the findings in this project is presented in Section 10.1. Suggestions for further research within this research area is discussed in Section 10.2.

10.1 Conclusion

The research questions are discussed in Chapter 9.

This thesis has presented a set of guidelines that can help ensure that developers are making systems that are useful in a therapeutic context. The research conducted was only through the interaction with therapists, not direct patient interaction, and thus the findings of this thesis should be suggestive rather than conclusive.

The advantage of using Nintendo Wii for treatment is not only on its specific games' potential, but also the cheap price of the system. This allows home training, and the involvement of the family in the patient's rehabilitation. Furthermore, Nintendo Wii is a handy device that could also be used in settings such as clinics or retirement houses.

Even with the Wiimote's obvious advantages there are still significant hurdles that need to be overcome before the Nintendo Wii system can be used in a wide range of physical rehabilitation contexts. There are very few options for customizing the Nintendo Wii console without buying the expensive official Game Development kit. The kit is intended for use by professional game

development companies only, and has a very strict requirements on how the kit should be used and where to be stored. In addition, there are very few software tools available to assist development.

Although the Wiimote has been successfully reverse engineered, there are some aspects that are poorly understood. The homebrew community will probably never get approved by Nintendo, and it will be difficult for them have their games used commercially. A workaround is to develop with a computer and use Wiimote or Wii Balance Board as user input device. This can work very well from a researcher's perspective.

The physical therapists who participated with their knowledge and experience in this study are enthusiastic. They imagine the use of a Wii system for rehabilitation to be very fun and motivational for the patients. The tests they conducted revealed that the Wii has the potential to be a very useful tool in their future rehabilatory work, and they are interested in participating in further development of rehabilitation games involving motion sensors.

Although further research and development of systems for use in physical rehabilitation is needed before the effectiveness and the usefulness of this therapy can be evaluated, we can already see that this form of rehabilitation has a lot of advantages compared to the traditional therapy, and we can foresee that this form of treatment probably will be used in addition to traditional physical therapy in the future.

10.2   Further Work

Further research on motion sensors in rehabilitation can take several paths.

One path is to change the field of study to other types of physical therapist work. I suggest that this can be for example in a rehabilitation center where the patients stay for longer time periods, unlike a hospital where the patients only stay for a few physical therapy sessions during the most critical phase of their treatment. Patients staying at rehabilitation centers can be assumed to be more motivated, as they select the treatment themselves.

Patients can be invited into the design phase of the development of rehabilitation games. A lot of the patients are creative, and can be a valuable resource together with a physical therapist as participants in a focus group or in a participatory design workshop.

Another path can be to try a different platform. There are currently tremendous advances being done in the development of this kind of technology. In this project the Nintendo Wii with its Wiimote and Balance Board was chosen, but during the project, two other big video game companies have released devices that use motion to interact with the system. Sony released its PlayStation Move, and Microsoft released its Kinect. Especially Microsoft Kinect is interesting, and has a very good potential to offer Nintendo competition. Microsoft's approach to the problem is very different. The patient does not have to hold any controllers - all motions of the body are recorded by Kinect's camera, and the ability to use voice commands can allow other interaction methods.

Nintendo Wii has several times updated the Nintendo Wii firmware to patch the system to prevent people to run unauthorized code on it. On the contrary, Microsoft has officially welcomed its customer to make their own software for Kinect.

The next step should in any case include the further development of prototypes which then will allow vital research to be done on the actual effectiveness of this type of treatment as an addition to classical treatment methods with different patient groups.

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Appendix A

Hello World in devkitPPC

Listing A.1: HelloWorld.c

```c
#include <stdio.h>
#include <stdlib.h>
#include <gccore.h>
#include <wiiuse/wpad.h>

static void *xfb = NULL;
static GXRModeObj *rmode = NULL;

//---------------------------------------------------------------------------------
int main(int argc, char **argv) {
//---------------------------------------------------------------------------------

        // Initialise the video system
        VIDEO_Init();

        // This function initialises the attached controllers
        WPAD_Init();

        // Obtain the preferred video mode from the system
        // This will correspond to the settings in the Wii menu
        rmode = VIDEO_GetPreferredMode(NULL);

        // Allocate memory for the display in the uncached region
        xfb = MEM_K0_TO_K1(SYS_AllocateFramebuffer(rmode));

        // Initialise the console, required for printf
        console_init(xfb,20,20,rmode->fbWidth,rmode->xfbHeight,rmode->fbWidth*VI_DISPLAY_PIX_SZ);

        // Set up the video registers with the chosen mode
        VIDEO_Configure(rmode);

        // Tell the video hardware where our display memory is
        VIDEO_SetNextFramebuffer(xfb);

        // Make the display visible
        VIDEO_SetBlack(FALSE);

        // Flush the video register changes to the hardware
        VIDEO_Flush();

        // Wait for Video setup to complete
        VIDEO_WaitVSync();
        if(rmode->viTVMode&VI_NON_INTERLACE) VIDEO_WaitVSync();


        // The console understands VT terminal escape codes
        // This positions the cursor on row 2, column 0
        // we can use variables for this with format codes too
        // e.g. printf ("\x1b[%d;%dH", row, column );
        printf("\x1b[2;0H");
```

```
        printf("Hello World!");

        while(1) {
                // Call WPAD_ScanPads each loop, this reads the latest controller states
                WPAD_ScanPads();

                // WPAD_ButtonsDown tells us which buttons were pressed in this loop
                // this is a "oneshot" state which will not do again until the button has been released
                u32 pressed = WPAD_ButtonsDown(0);

                // We return to the launcher application via exit
                if ( pressed & WPAD_BUTTON_HOME ) exit(0);

                // Wait for the next frame
                VIDEO_WaitVSync();
        }

        return 0;
}
```

Appendix B

GlovePIE Wii Motion Plus

Listing B.1: WiiMotionPlus3.pie

```
ï»¿/*
    WiiMotion  Plus  Mouse                              v  2010.10.10
    by  William  Young

*/

var.MoveButton = !wiimote.A
mouse.LeftButton = wiimote.Minus
mouse.RightButton = wiimote.Plus
mouse.MiddleButton = wiimote.Down

var.Speed = 75    // 0 to 100

PIE.FrameRate = 8hz
if wiimote.HasMotionPlus = false then debug = "WiiMotion Plus NOT DETECTED!"
if wiimote.HasMotionPlus = true and var.MoveButton = true {
    var.Yaw = wiimote.MotionPlus.GyroYaw
    var.Pitch = wiimote.MotionPlus.GyroPitch
    var.SP = wiimote.SmoothPitch/2

    if SameValue( Smooth(wiimote.SmoothRoll, 10), wiimote.SmoothRoll, 10)
    then var.Roll = Smooth(wiimote.SmoothRoll, 10) else var.Roll = wiimote.SmoothRoll

    var.random = Random(10)

    var.SP = int (var.SP)
    var.SP2 = var.SP / 100
    var.MouseY = 0.92
    var.MouseX = 0.5 + var.SP2

    mouse.x = var.MouseX
    mouse.y = var.MouseY

}
if var.MoveButton = false {
    var.MouseX = mouse.DirectInputX
    var.MouseY = mouse.DirectInputY

}
```

Appendix C

Therapist's Review of Wii Sport and Wii Fit

	Perfekt 10	Cykling	Golf	Heading	Slalom Ski	Ski jump
Ferdigheter						
Kondisjon						
Styrke						x
Beveglighet			x			x
Balanse	x	x	x	x	x	x
Koordinasjon	x	X	x	x	x	x
Funksjonalitet						
Hastighet	Høy	tilpasses gjennom hvor fort man stepper		høy	justeres	ok
Forstyrrelser	Lyd	Lyd	nei	Flygende objekter	Lengre avstand mellom flagg	nei
Vanskelighetsgrad	Høy	Ok	Høy	høy	Høy/ok	Ok
Forståelse	??	Ok	??	Ok	Ok	Ok
Overførbarhet		Gangfunksjon?		ok	Ok	Krever timing av knestrekk
Tid/varighet	lang	Lang, må treffe antall mål		Lang?	ok	Ok
Egnet med tilpasninger for:						
Ortopediske pas.		X		X	X	X
Nevrol. Pas.		X		X	X	X
Reuma		X		X	X	X
Barn		X		X	X	X
eldre		X		X	X	X
Bevegelseskrav:						
Rotasjon med bekken	x		x		X	
Gangfunksjon/step		x				
Gripeevne		x	x			
Skulderstabilitet			x			
Rotasjoner thorax			x		X	
Skulder: Abd/add Fleks/ekst Rot			X X x			
Nakke - sidebøy				x		
Tyngdeøverføring		x	x	x	X	
Kne						X

Fleks/ekst rot	x				x
hofte Abd/add Fleks/ekt Rot	x				x
Utgangsstillinger					
Stående	x	x	x		
Sittende					
Knestående					
Håndstående					

	Table tilt	Tight-rope	Balance bubble	Penguin slide	Snowboard slalom	ZAZEN
Ferdigheter						
Kondisjon						
Styrke						X
Beveglighet	x		x	x	x	
Balanse	x	x	x	x	x	X
Koordinasjon	x	x	x	x	x	X
Funksjonalitet						
Hastighet	høy	ok	ok	høy	Høy	
Forstyrrelser		Flygende objekter	ja	ja		
Vanskelighetsgrad	Gradvis økende	høy	Mer avstand til sidene	høy	høy	ok
Forståelse	ok	ok	ok	ok	ok	Ok
Overførbarhet		???	ja	Nei		
Tid/varighet	Kort tid		justeringer	Lang		
Egnet med tilpasninger for:						
Ortopediske pas.			X			
Nevrol. Pas.			X		x	X
Reuma			X		X	X
Barn			X	x	X	X
eldre			X		X	x
Bevegelseskrav:						
Rotasjon med bekken						

	Perfekt 10	Cykling	Golf	Heading	Slalom Ski	Ski jump
Ferdigheter						
Kondisjon						
Styrke						x
Beveglighet			x			x
Balanse	x	x	x	x	x	x
Koordinasjon	x	X	x	x	x	x
Funksjonalitet						
Hastighet	Høy	tilpasses gjennom hvor fort man stepper		høy	justeres	ok
Forstyrrelser	Lyd	Lyd	nei	Flygende objekter	Lengre avstand mellom flagg	nei
Vanskelighetsgrad	Høy	Ok	Høy	høy	Høy/ok	Ok
Forståelse	??	Ok	??	Ok	Ok	Ok
Overførbarhet		Gangfunksjon?		ok	Ok	Krever timing av knestrekk
Tid/varighet	lang	Lang, må treffe antall mål		Lang?	ok	Ok
Egnet med tilpasninger for:						
Ortopediske pas.		X		X	X	X
Nevrol. Pas.		X		X	X	X
Reuma		X		X	X	X
Barn		X		X	X	X
eldre		X		X	X	X
Bevegelseskrav:						
Rotasjon med bekken	x		x		X	
Gangfunksjon/step		x				
Gripeevne		x	x			
Skulderstabilitet			x			
Rotasjoner thorax			x		X	
Skulder: Abd/add Fleks/ekst Rot			X X x			
Nakke - sidebøy				x		
Tyngdeøverføring		x	x	x	X	
Kne						X

Appendix D

Written Consent

The written consent the participants signed.

Brukersentrert utvikling av Nintendo Wii spill for fysisk rehabilitering.

WiiHab

Deltakelse på workshop ved NSEP/NTNU.

Samtykkeerklæring

Jeg har mottatt skriftlig og muntlig informasjon om studien, og fått
anledning til å stille spørsmål. Jeg er klar over at det er frivillig å
delta, og at jeg kan trekke meg fra studien når som helst uten å oppgi
noen grunn. Jeg samtykker i å delta i studien.

Trondheim,_____

_____
Underskrift

Appendix E

Non-Disclosure Agreement

The non-disclosure agreement between the researcher and the therapists.

Taushetserklæring

Jeg er kjent med at jeg gjennom mitt arbeid kan få tilgang til taushetsbelagte opplysninger, og forplikter meg til å overholde bestemmelsene om taushetsplikt slik de framkommer i foretakets prosedyre, med grunnlag i nedenfor stående lovbestemmelser:

Alle som arbeider ved St. Olavs Hospital, studenter, lærere ved høyskole og universitet, partnere/leverandører plikter å hindre at andre får adgang eller kjennskap til det hun/han i forbindelse med tjenesten eller arbeidet får vite om folks legems- eller sykdomsforhold eller andre personlige forhold som de får vite om i egenskap av å være helsepersonell og/eller i tjeneste for et offentlig forvaltningsorgan.
Taushetsplikten gjelder også:

• pasientens fødested, fødselsdato, personnummer, pseudonym, statsborgerforhold, sivilstand, yrke, bopel og arbeidssted. Opplysning om en pasients oppholdssted kan likevel gis når det er klart at det ikke vil skade tilliten til helseinstitusjonen.

• tekniske innretninger og fremgangsmåter samt drifts- eller forretningsforhold som det vil være av konkurransemessig betydning å hemmeligholde av hensyn til den som opplysningen angår.

Opplysninger til andre forvaltningsorganer kan bare gis når dette er nødvendig for å bidra til løsning av oppgaver etter forvaltningsloven, eller for å forebygge vesentlig fare for liv eller alvorlig skade for noens helse.
"Taushetsplikten gjelder også etter at du har avsluttet tjenesten eller arbeidet. Overforstående opplysninger kan ikke utnyttes i egen virksomhet eller i tjeneste eller arbeid for andre."
Den som forsettelig eller grovt uaktsomt krenker taushetsplikten kan straffes med bøter eller med fengsel inntil 6 måneder.
Begås taushetsbrudd i den hensikt å tilvende seg eller andre en uberettiget vinning er stafferammen 3 år. Det samme gjelder når det foreligger andre særdeles skjerpende omstendigheter.

St. Olavs Hospital   Dato_____Navn med blokkbokstaver :_____

Signatur:_____Avdeling firmatilhørighet :_____

Følgende lovparagrafer omhandler taushetsplikten og brudd på taushetsplikten:

        • Helsepersonelloven § 21

        • Lov om spesialisthelsetjenesten § 6.1

        • Forvaltningsloven § 13

        • Straffeloven § 121

        • Lov om folkeregistrering §13

        • Lov om helseregistre og behandling av helseopplysninger § 15

        • Lov om personopplysninger kap. II

        • Forskrift til personopplysningsloven, kap. 2

        • Pasientrettighetsloven tas med, §3-6 Rett til vern mot spredning av opplysninger

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