Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Medicine and Health Sciences
Department of Neuromedicine and Movement Science

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Motivation for gait training and change in gait symmetry with a VR-gait training game for stroke patients.

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Supervisor: Beatrix Vereijken, co-supervisor: Elise Klæbo Vonstad
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Abstract

Introduction: The use of virtual reality (VR) in stroke rehabilitation has increased in recent years, likely due to an assumed relationship with increased motivation and adherence. However, few VR-intervention studies have measured motivation in a standardized way. Furthermore, little is known about different gait specific training tasks. **Aim:** Examine how different gaming tasks in a fully immersive VR-gait training game affect motivation and gait symmetry in stroke patients, and the correlation between motivation and change in symmetry. **Methods:** Ten stroke patients played a single gait training session with a fully immersive VR-game. The game consisted of three different gait specific training tasks: Hit Tiles, Avoid Strips and a Cognitive Motor task. The game was played by walking on a treadmill, wearing a VR-headset and a safety harness, and used the participants foot movement to control the game, recorded using reflective markers and an infrared 3D-camera system. The Intrinsic Motivation Inventory (IM) and symmetry ratio was used to assess motivation and step length symmetry. **Results:** Generally, high motivation scores were reported on all three tasks. Only on the Perceived competence subscale, participants scored slightly lower on the Cognitive Motor task. The results on step length symmetry showed that symmetry ratio was not significantly different with the VR-headset compared to walking without it. In the three gaming tasks, the symmetry ratio was slightly closer to 1 across all three tasks, but not significantly differences from the baseline symmetry. The symmetry ratio for the Avoid Strips task was closer to the significance level than the Hit Tiles task and Cognitive Motor task. The results on the correlation between motivation and change in symmetry showed no clear pattern. **Discussion and conclusion:** The high motivation scores across tasks is a promising result, encouraging more research and implementation of this type of VR-game in stroke rehabilitation. Longer intervention duration is needed to see whether the high motivation scores will sustain. Furthermore, the game seemed to have the potential to improve step length symmetry, but a longer time frame is needed for significant improvements in symmetry and to detect possible differences between tasks. Due to small differences in motivation across tasks and small changes in symmetry, conclusions on the potential relation between the two were difficult to draw. Future research should develop a better measure for motivation, use longer intervention duration and secure minimal technical difficulties to examine how different gaming tasks affect motivation and step length symmetry in stroke patients and the potential correlation between the two. With this knowledge, a clinical trial designed to evaluate the effect of the VR-system on gait-related functions would come within reach.

Sammendrag

Introduksjon: I løpet av de siste årene det vært en stor økning i bruk av virtuell virkelighet (VR) i slagrehabilitering, mye grunnet antatt økt motivasjon og etterlevelse av treningen. Men få studier har malt motivasjon på en standardisert måte. Videre mangler det kunnskap om gangspesifikke treningsoppgaver **Problemstilling:** Undersøke hvordan ulike spilloppgaver i et gangtreningsspill i VR-headset påvirker motivasjon og gangsymmetri hos slagpasienter, og den potensielle korrelasjonen mellom motivasjon og endring i symmetri. **Metode:** Ti slagpasienter spilte én gangtreningsøkt med et VR-gangtreningsspill. Spillet bestod av tre ulike gangtreningsoppgaver: Treffe Fliser, Unngå Lister og en Kognitiv Motor oppgave. Deltakerne spilte spillet ved at de gikk på en tredemølle samtidig som de hadde på et VR-headset og en sikkerhetssele. Deltakerne brukte bevegelse av føttene sine for å kontrollere spillet, som ble målt ved bruk av reflekterende markører og et infrarødt 3D-kamera system. The Intrinsic Motivation Inventory (IM) og symmetri ratio ble brukt for å evaluere motivasjon og steg lengde symmetri. **Resultater:** Høye motivasjonsscorer ble rapportert på alle tre spilloppgaver. Kun på Perceived Competence subskalaen scoret deltakerne noe lavere på den Kognitive Motoriske oppgaven. Resultatet på steglengde symmetri viste at symmetri ratio ikke endret seg signifikant når deltakerne gikk med VR-headset sammenlignet med når de gikk uten. På de tre spilloppgavene var symmetri ratio nærmere 1, med små, ikke-signifikante forskjeller fra utgangssymmetri. Symmetri ratio på Unngå Lister-oppgaven var nærmere signifikant enn på Treffe Lister- og den Kognitive Motoriske-oppgaven. Resultatet på korrelasjon mellom motivasjon og endring i symmetri viste ingen klare mønstre. **Diskusjon og konklusjon:** De høye motivasjonsscorene på alle spilloppgaver er et oppløftende resultat som oppmuntrer for videre forskning og implementering av denne typen VR-spill i slagrehabilitering. Men intervensjoner med lengre varighet er nødvendig for å undersøke de langvarige effektene på motivasjon. Videre ser spillet ut til å kunne forbedre steglengde symmetri, men lengre spill-varighet er nødvendig for å finne signifikante forbedringer i symmetri og mulige forskjeller mellom spilloppgavene. På grunn av lite variasjon i motivasjon på tvers av spilloppgaver og små endringer i symmetri er det vanskelig å dra konklusjoner rundt relasjonen mellom dem. Fremtidig forskning burde utvikle en bedre metode for å måle motivasjon, ha lengre varighet på intervensjonen og sikre minimalt med tekniske problemer for å undersøke hvordan ulike spilloppgaver påvirker motivasjon og steg lengde symmetri og den potensielle korrelasjonen mellom disse. Med denne kunnskapen vil et klinisk studie designet for å evaluere effekten av en slikt VR-system på gangrelaterte funksjoner innen være rekkevidde.

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Table of content

Introduction

Stroke is one of the most commonly occurring cardiovascular diseases in modern society. According to the World Stroke Organization, 13.7 million new strokes occur every year (Feigin et al., 2019), and one in four people over the age of 25 will have a stroke during their lifetime (GBD Lifetime Risk of Stroke Collaborators, 2018). The effects of stroke may include sensory, motor, and cognitive impairment, as well as reduced ability to perform activities of daily living and participate in social community activities (Miller et al., 2010). These effects often lead to lifelong critical disability and reduced quality of life (Patel et al., 2006; Sturm et al., 2004).

Depending on the brain area damaged, the specific type of impairment following stroke varies greatly. However, hemiparesis, a paralysis that affects one side of the body, is one of the most frequently occurring impairments after stroke (Macko et al., 2002). Hemiparesis often leads to several negative walking-related consequences and an asymmetric gait pattern, which puts extra strain on the body, is ineffective and increases risk of fall (Wüest, van de Langenberg, & de Bruin, 2014). The loss or impairment of gait function is one of the most devastating disabilities after stroke (Flansbjer, Downham, & Lexell, 2006), and is reported by patients to be the most important function to regain (Bohannon, Andrews, & Smith, 1988).

While most recovery is typically made in the acute phase (<3 months post-stroke) (Dam et al., 1993; Jørgensen, Nakayama, Raaschou, & Olsen, 1995), patients may also make improvements on functional tasks in the chronic phase through rehabilitation programs (Teasell, Fernandez, McIntyre, & Mehta, 2014). Gait function is usually trained on a treadmill using a safety harness, and treadmill training with partly body weight support has been shown to positively affect gait related abilities (Hesse, 2008). However, traditional rehabilitation programs often lack high motivational levels, possibly because such training programs involve slow, repetitive and often painful movements, and are perceived as boring. This may hinder patients in completing the program and in continuing training at home, which can lead to a slower or even ineffective rehabilitation process (Gamboa, Ruiz, & Trujillo, 2018).

In recent years, the use of exergaming and virtual reality (VR) technology has increased in stroke rehabilitation settings (Laver et al., 2017). VR-technology is defined as "*use of interactive stimulations created with computer hardware and software to present users with opportunities to engage in environments that appear and feel similar to real world objects* *and events*" (Weiss et al., 2006). Virtual reality includes fully immersive virtual environments (VE), such as wearing head mounted displays (HMDs), and less immersive forms, such as a desktop-based and cave automatic virtual environments (Guo, Samaraweera, & Quarles, 2013). Adding a virtual reality environment to the treadmill training provides the opportunity to use game elements that can make the training more fun and motivating. This may be an attractive alternative to increase motivation and adherence in stroke patients (Skjæret-Maroni et al., 2016).

Furthermore, a major advantage of using VR technology in rehabilitation settings is the possibility to implement tasks and elements in a training situation that would not be feasible in the real world without putting the patient at risk of falls, or other unwanted or dangerous events. One may implement tasks that require adapting movement patterns to various obstacles or situations often encountered outdoors. For example, that one must keep track of several things while walking, which simultaneously challenges the patient's physical capacity and cognitive attention. These are skills that are necessary to successfully navigate through different situations in daily life (Skjæret-Maroni et al., 2016), and are therefore valuable in a rehabilitation setting.

Additionally, virtual reality technology permits adaptation of training environments to individual needs and goals, such as gradual progression and multisensory feedback. Multisensory feedback allows for immediate adjustment, giving a reward when a task is executed correctly, and encouragement to try again if the trial was incorrect (Subramanian, Lourenco, Chilingaryan, Sveistrup, & Levin, 2013). These aspects are generally believed to increase motivation for and adherence to a training program (Skjæret et al., 2016).

Because of the hypothesized positive effects of VR on motivation for and adherence to training, more and more attention has turned to the effectiveness of VR on lower limb function. Studies show that by using VR, patients have been able to improve balance and/or gait parameters to the same (Gibbons, Thomson, de Noronha, & Joseph, 2016; Luque-Moreno et al., 2015) or a greater degree (Darekar, McFadyen, Lamontagne, & Fung, 2015; de Rooij, van de Port, & Meijer, 2016) compared to conventional therapy. However, more empirical evidence is required to support these claims (Laver et al., 2017). In addition, few studies have investigated the effect of fully immersive treadmill training (Jung, Yu, & Kang, 2012).

The positive effects of VR are believed to be partly attributable to increased engagement and motivation (Meldrum et al., 2015). However, few studies have actually measured motivation.

According to a scoping review from 2019 (Rohrbach, Chicklis, & Levac, 2019) motivation has been mentioned in several VR intervention studies. However, a consensus on definition and terminology is lacking. Of the included studies in their review, 138 studies have described motivation, engagement, enjoyment, presence or immersion in their papers, but few used a standardized or even non-standardized outcome to actually measure this. Of those who did measure motivation, the most frequently used measure was the Intrinsic Motivation Inventory (IMI) (Rohrbach et al., 2019), which has been validated for stroke patients in English (Colombo et al., 2007).

Since few studies have measured motivation in a standardized way, the connection between motivation and motor learning is uncertain (Rohrbach et al., 2019). Many researchers use motivation as a rationale for use of VR in stroke rehabilitation, and as an explanation for a successive intervention, but none have used statistical interference to link motivation to motor outcome (Rohrbach et al., 2019)

The current study

As mentioned previously, few studies have measured motivation, hence little is known about how different gaming tasks affect motivation and gait patterns. A recent study from 2020 revealed that different motor tasks and environmental constraints in a virtual environment affected gait pattern in healthy adults (Bovim, Gjesdal, Mæland, Aaslund, & Bogen, 2020). To our knowledge, no studies have examined the impact of gait specific training tasks on motivation and improvement in gait patterns in stroke patients.

A custom designed fully immersive VR-game system has been developed at NTNU IDI with the aim of providing fun, motivating gait training with the possibility to implement additional cognitive tasks by using elements in a virtual environment. An earlier usability study on the VR-game revealed that both stroke patients and therapists were positive about the system and enjoyed the VR-game (Endresen, 2019).

To specifically address gait asymmetry in stroke patients, the fully immersive VR-game has been developed further into a stepping-stone game, consisting of specific gait training tasks aiming to manipulate step length in different ways, and with the possibility to do a cognitive task simultaneously. A previous study (Skjæret-Maroni et al., 2016) revealed that adding an additional cognitive element to an exergame is perceived as fun and challenging by older participants, but might have unintended effects on the movements performed to play the exergame. It is interesting to see whether this is also the case in stroke patients. This knowledge is useful before designing and running a clinical trial to evaluate the effect of the VR system on gait-related functions.

Therefore, the research questions for this paper are: 1) how do different gait training tasks affect motivation and gait symmetry in stroke patients, and 2) to what extent is motivation correlated with changes in gait symmetry?

Methods

Participants

Ten stroke patients in subacute or chronic phase (>3 months) post stroke were recruited for the study. The inclusion criteria were age > 18 years, ability to walk safely on a treadmill, receive and understand instructions, and ability to answer a questionnaire. Participants were excluded if they had epilepsy or other conditions that would affect their ability to walk safely on a treadmill while wearing a VR headset and interacting with a virtual environment.

Participants were recruited from St. Olavs Hospital, Clinic for Physical Medicine and Rehabilitation, Department of Acquired Brain Injury, by a member of the project group whose main employment was as a physical therapist in the clinic. All participants provided informed, written consent. The study was approved by the Regional Ethical Committee of Medical and Health Research Ethics November 26th, 2019, nr. 50926.

Equipment

The VR-game

The VR-game used in this study was custom designed at the NTNU Vizlab, Department of Informatics and Computer Technology. The game was played by walking on a treadmill (X-erfit 400 pro-run, X-ERFIT) using a VR-headset (HTC Vive, HTC) and wearing a safety harness (iHarness, LiteGait, US). The game used a 3D motion capture system (describe in detail below) to allow for online detection of the timing and location of foot placement.

The game was played in a winter landscape, where participants walked on a pathway. The game consisted of three different gaming tasks: Hit Tiles (Figure 1), Avoid Strips (Figure 2) and a Cognitive Motor task (Figure 3). The aim of the first two tasks was to train gait symmetry by instructing where to step by placing tiles or strips along the pathway. The tiles/strips were placed according to the participants baseline gait pattern and adjusted to modulate step length asymmetry. Hitting the tiles and stepping over the strips were two different ways of instructing where to step, with the aim of influencing foot placement to achieve a more symmetrical gait pattern. Both tasks were included because of the uncertainty of whether stroke patients are more motived by tasks aimed at stepping on versus over objects, and what kind of instruction might be easier to follow. The aim of including the Cognitive Motor task was to see whether the participants were able to perform a cognitive task while attempting to hit the tiles. The Cognitive Motor task was to find specific fruits/vegetables in the sky and shoot them by moving the head and focusing on the object with the VR-headset.

A representation of the treadmill was shown in the game (see Figure 1, Figure 2, Figure 3), where the participants could start (green button) and stop (red button) the treadmill, adjust speed (plus and minus sign at the right), and see percentage score on each foot (small squares shown in Figure 3). The movements of the participants' feet were shown in the big square in the middle of the treadmill.

Feedback on performance was given by the percentage score on each foot and by colors on the tiles/stripes. Blue or green if they hit/avoided the tiles/stripes well, yellow or red if they did not. In the Cognitive Motor task, points were only given when shooting the correct fruit/vegetable, instructed by a small square on top of the treadmill in the game, for example red chili pepper as shown in Figure 3. When shooting the correct fruit/vegetable, the fruit/vegetable exploded with fireworks, disappeared, and a small number showing successful hits was displayed. All fruit/vegetables appeared randomly in the sky, nudging participants to move their head in all directions.

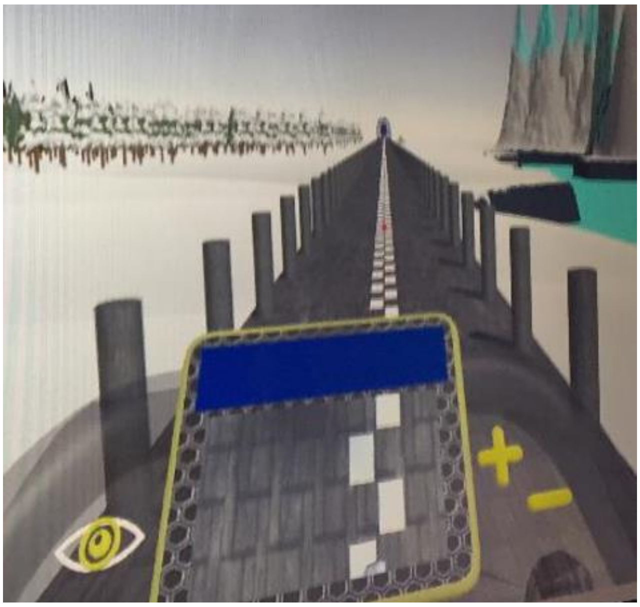


Figure 1. Representation of the virtual treadmill during the Hit Tiles task, with some of the features. Tiles placed according to baseline gait pattern.

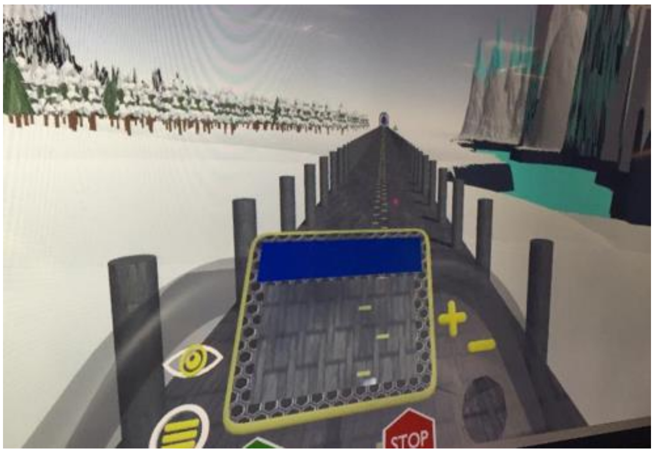


Figure 2. Representation of the virtual treadmill during the Avoid Strips task, with some of the features. Strips placed according to baseline gait pattern.

Figure 3. Representation of the virtual treadmill during the Cognitive Motor task, with some of the features. Tiles placed according to baseline gait pattern in addition to the additional cognitive task with the fruit/vegetables appearing in the sky.

Adjustment of tiles/strips

The adjustment of tiles/strips was done automatically by the game and based on step length measured in a calibration recording. The foot with the longest step length was used as the reference for symmetrical gait, irrespective of whether this was the affected or non-affected leg. The foot with the shortest step length was adjusted gradually towards this step length by placing the tiles and strips progressively forward. The step length and distance of the tiles/strips of the other leg remained unchanged.

The adjustment was done over 380 meters long distance of tiles/strips. To be able to accelerate/decelerate, there was a 10-meter distance before and after the tiles/strips, resulting in a total maximum pathway of 400 meter. To adjust the tiles/strips, the game calculated the distance from the first tile/list, divided by total adjustment pathway and multiplied with difference in step length between left and right leg. In this manner, the tiles/strips became more and more adjusted as the participants walked further down the pathway, until the adjustment goal of 100 % at the end of the maximum pathway. The first tile/strip corresponded to 0% adjustment, while the last tile/strip corresponded to 100 % adjustment (Påsche Sørenmo, 2019). Due to differences in gait speed, participants walked different lengths of pathways (see further below).

Movement data, treadmill and VR-headset

The game was run from a computer which was connected to an 82” TV-screen. The TV-screen was not used by the participants, it was only there for the researchers to see the same virtual environment as the participant. Movement data was collected by a Qualisys 3D motion capture system (OQUS MX400/MX300, 100Hz, Qualisys AB) consisting of seven infrared cameras. The cameras traced the movements of 18 reflective markers placed on 18 specific anatomical locations on the lower body of the participants.

The game, Qualisys Track Manager (QTM), VR-headset and the treadmill were connected through Unity (Unity Technologies). The treadmill speed was synced to the game through an Arduino connecting the treadmill to Unity. Video was captured by a digital camera (GoPro Hero 3+, 30 Hz, GoPro Inc), and used to identify time spent walking on tiles/stripes and the cause of abnormal events in the results. The placement of the TV-screen, computer, treadmill, OQUS cameras, HTC-vive base stations and go-pro camera can be seen in

Figure 4.

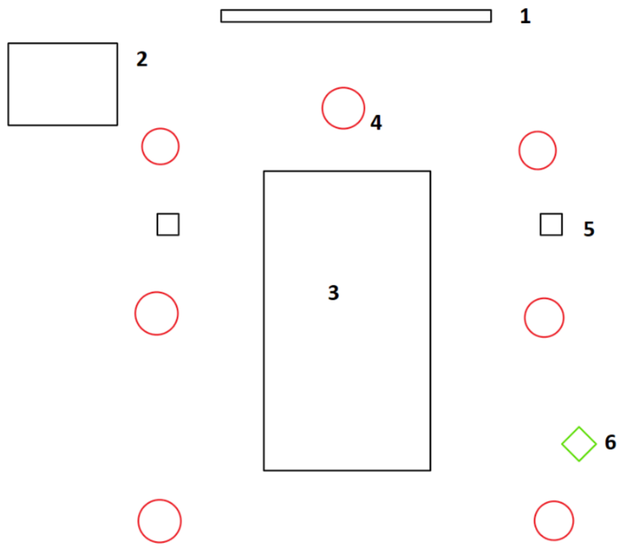


Figure 4. Illustration of the Lab setup. The placement of the TV-screen in the front (1), the computer running the game on the left (2), the treadmill in the middle (3), with the seven OQUS cameras (red circles, 4), HTC-vive base stations (black squares, 5), and GoPro (green rhomb, 6). The participant walked on the treadmill facing the TV-screen.

Reflective markers were placed according to the Plug-in-gait lower body marker placement guide (Vicon Motion Systems Ltd, 2016), but only the foot model was used to control the game and in further analysis in the current study. The foot model included a marker on the first metatarsal, lateral malleolus and calcaneus. Markers were attached using double sided skin-friendly tape and velcro. The hip markers were placed on the harness.

Examination

Participants' height and weight were measured using an analog scale (SECA 760) and measuring tape. A kinesthetic sensation test from the Nottingham Sensory Assessment for Stroke Patients (Lincoln, Jackson, & Adams, 1998) was conducted by an experienced physical therapist. A goniometer and measuring tape were used to measure range of motion (ROM) and for anthropometric measures of the lower body segments on an examination table. To calculate preferred walking speed on the floor, an overground 4-meter gait speed test (Karpman, LeBrasseur, DePew, Novotny, & Benzo, 2014) was conducted.

Motivation

Participants' motivation was assessed by the Intrinsic Motivation Inventory Questionnaire (IMI), which is a multidimensional questionnaire developed to assess motivation for target activities (Deci, Eghrari, Patrick, & Leone, 1994; McAuley, Duncan, & Tammen, 1989). IMI is taken from the cognitive evaluation theory, which relates to intrinsic motivation, that is motivation that is based on the enjoyment of behaving "for its own sake"(Ryan & Deci, 2000). The questionnaire evaluates participants' Interest/enjoyment, Perceived competence, Effort/importance, Value/usefulness, felt Pressure and tension, and Perceived choice while performing a given activity, resulting in six subscales. The Interest/enjoyment subscale is the only subscale directly assessing self-reported intrinsic motivation, while the other subscales are predictors of intrinsic motivation. The questionnaire consists of items from the subscales with a varying number of elements (see Appendix 2). All subscales have shown to be factor analytically coherent and stable across a different tasks, conditions and settings (Self-Determination Theory, 2019).

In this study we used the following five subscales: Interest/enjoyment, Perceived competence, Effort/importance, Pressure/tension and Value/usefulness. The subscale Perceived choice was excluded, due to not being relevant as participants took part in the study voluntarily.

Three different versions of the questionnaire were made. Each version consisted of 15 questions, where type of gaming task differed in the three versions. The questions were adapted to the activity, so that “the activity” was changed to the gaming task in question to better reflect what we were interested in. According to the literature, these adaptations will not affect the validity (McAuley et al., 1989; Self-Determination Theory, 2019). The questionnaire was translated to Norwegian (see Appendix 1), tested on 14 pilots, and adjusted in response to their feedback before being used in this study. Four additional questions were asked to further compare the different gaming tasks. These latter questions concerned what gaming task they liked the most/were more motivated by/was too difficult and what elements in the training situation had the biggest impact on their motivation (see Appendix 1).

Procedure

Before being introduced to the entire procedure by a PowerPoint presentation, participants were asked to read and sign an informed consent form (Appendix 3). Background information was collected in a short interview, and height, weight, kinesthetic sensation, ROM, length and width of lower body segments were measured. Then the 4-meter overground gait speed test was conducted. Participants were instructed to walk three times, in a comfortable walking speed. The average speed from the three trials was used. Reflective markers were then placed on the participants lower body, and the participant was offered a short break if necessary.

Then, the participant was welcomed to the treadmill, secured with the harness, and hip-markers were placed. Using the walking speed from the 4-meter gait speed test as a reference point, the participant’s preferred walking speed on the treadmill was found. This was used as walking speed on all remaining measurements. When preferred walking speed was found, a baseline recording was conducted to compare gait pattern with and without the VR-game. The participant was asked to walk normally for three minutes without the VR-headset to get comfortable with walking on the treadmill and the with harness.

After the baseline recording, the VR-headset was placed, and an instruction path was shown in the virtual environment. This gave the participants an opportunity to get familiar with wearing the headset and with moving in the virtual environment. The participants were instructed on how to focus with the VR-headset to press buttons in the game, how to start and stop the treadmill, adjust speed and how the big screen in the middle of the treadmill was as an aid to see and time their step. No measurements were taken during this familiarization period.

Then a reference VR recording was conducted to calibrate and measure the participants’ gait pattern when using the VR-headset without manipulating their gait pattern. The participant was instructed to start the treadmill, increase the speed to standard and focus on a blue circle to start a calibration when standard speed was achieved. Gait pattern was measured for 30 seconds and used for placement of tiles/stripes in the game. The speed used in the VR reference recording was saved in the game and used for the following gaming tasks.

A short break was offered to the participant before starting the game. First, the participants played the Hit Tiles task and Avoid Strips task, in counterbalanced order across participants, and then proceeded with the Cognitive Motor task. Depending on the task, the participants were instructed to hit tiles/avoid strips/shoot specific fruits/vegetables and informed about the feedback on performance from the game. Then the participants were instructed to start the treadmill and focus on a star on the treadmill to get up to standard speed. If the participant found it too difficult to find an object and hit the tiles simultaneously in the Cognitive Motor task, they were instructed to focus on one of them. Each round lasted three minutes. One member of the project group stood near the participants the whole time to ensure safety while walking on the treadmill. An overview of all recordings with their purposes are shown in Table 1.

Between each gaming task the participant was asked to sit down and answer the IMI. The participants scored their motivation on a 7-point Likert Scale, where 1=strongly disagree and 7=strongly agree. The participant was instructed to answer as honest and critical as possible. To reduce potential problems because of aphasia, the items were read aloud by a project member, and the participants scored their motivation according to the scale verbally or by pointing at the preferred point on the Likert scale (see Appendix 1). The additional questions were answered by pointing on pictures illustrating the different gaming tasks (see Appendix 1).

Table 1. All recordings during the procedure with their purposes.

Recording	Purpose
Baseline recording on treadmill without VR-headset	Measure baseline gait pattern to compare with gait pattern in the game.
Reference VR recording	Calibrate and measure gait pattern with VR-headset without gaming tasks. Save information about gait pattern and walking speed for placement of tiles/strips in the game.
VR game, Hit Tiles task	Measure gait pattern when step length was adjusted by tiles.
VR game, Avoid Strips task	Measure gait pattern when step length was adjusted by strips.
VR game, Cognitive Motor task	Measure gait pattern when step length was adjusted by tiles and with the additional cognitive task.

Data analysis

For each of the gaming tasks, first and last heel strike on tiles/stripes on left and right foot was identified in QTM, and the file was cut so that the file only included measurement of gait pattern when participants were walking on tiles/lists. This was done to get a recording of their gait pattern when gradually adjusted.

The data was exported from QTM to Vicon ProCalc (v.1.3) for calculating spatio-temporal parameters using the Plug-in-Gait biomechanical model (Vicon Motion Systems Ltd, 2016). The output variables from Vicon ProCalc were stride length, stride time, gait speed, double support, single support, step length, step width, and step/min. Only step length was used to evaluate gait symmetry in this paper, as this was targeted by the game.

Calculation of variables

The IMI-questionnaire resulted in a Total IMI-score ranging from 1-7 and five subscales scores ranging from 1-7 for each gaming task. Generally, a high score was a positive indication for motivation. However, one exception was item number 10 (see Appendix 1) from the Pressure/tension subscale. This was a reversed item, where a high score indicated that the participant felt more pressured and tense. Therefore, the score on this item was subtracted from 8, and the result was used as the item score for that item. In this way a higher score on the Pressure/tension subscale was a positive indication for motivation as well.

IBM SPSS Statistics 25 (IBM, USA) was used to calculate new variables such as the five subscales scores and Total IMI-score, speed (m/s), distance walked (m) on tiles/strips, percentage adjustment at the end of each round, mean step length, symmetry ratio and change in symmetry.

Subscales scores from IMI were calculated by averaging the item scores for the items on each subscale. Total IMI was calculated by taking the average of all five subscales.

As mentioned earlier, the recordings from the three gaming tasks consisted of gait cycles from first to last heel strike on tiles/stripes. This gave time frames for when the participants were walking on tiles/strips. These time frames were used to calculate distance walked in tiles/stripes by multiplying the time frames with speed in m/s on the treadmill. Percentage adjustment was calculated by dividing distance walked on tiles/strips with 380 (maximum distance of tiles/strips) and multiplied with 100.

To calculate mean step length per foot, all gait cycles from the baseline and reference VR recording were used, as there was no manipulation of step length. For the three gaming tasks, the 5 last gait cycles were used to calculate the mean step length after adjustment of step length by the game.

There are several different definitions of symmetry in the literature, with no consensus about the best measure. An article from 2010 (Patterson, Gage, Brooks, Black, & McIlroy, 2010) compared different ways to evaluate gait symmetry after stroke, and found no single method to have a unique advantage over another. Therefore, they recommended the use of the "symmetry ratio", because of its easy interpretation. The symmetry ratio was also the method used in this study.

In accordance to the article (Patterson et al., 2010), the symmetry ratio was defined as:

$$\frac{mean\ step\ length\ paretic\ leg}{mean\ step\ non{-}paretic\ leg}.$$

To assess step length symmetry, mean step length calculated for all gait cycles in the baseline and reference VR recording and last 5 cycles for the three gaming tasks were used. A symmetry ratio >1 indicates longer step length on paretic leg, while symmetry ratio <1 indicates longer step length on non-paretic leg. Values close to 1 indicate perfect gait symmetry (Patterson et al., 2010). Because the direction of asymmetry was not relevant for this study, symmetry values <1 were inversed for further use in statistical analysis.

Change in symmetry is presented as percentage to get relative change. The change was calculated by finding the absolute difference in symmetry ratio between the baseline recording and the relevant gaming task, divided by the symmetry ratio in the baseline recording, and multiplied with 100%. This was done for all three gaming tasks.

Statistical analysis

All statistical analyses were done in SPSS. Data was checked for outliers by visual inspection through graphs and descriptive statistics. Outliers (±3 standard deviation (SD) from the mean) were removed.

All variables were tested for normality using the Shapiro-Wilk test with significance level set to 0.05, and through visual assessment of plots. Despite the Shapiro-Wilk test claiming the assumption of normality in some of the variables were not violated, the variables did not seem normally distributed from visual inspection of histograms and QQ-plots. Because normality tests have less power to assess normality with small sample size (Öztuna, Elhan, & Tüccar, 2006) and the histograms and QQ-plots were difficult to interpret, none of the variables could be deemed normally distributed. Thus, median and interquartile range (IQR) are reported for all variables and non-parametric tests are used for all variables.

An Independent samples Mann Whitney U test was used to test for potential sex-differences in the demographics of the participants. Because there were no significant sex-differences, demographics for all participants are presented together.

To test differences in motivation between the three gaming tasks, a Wilcoxon Signed Rank Test was conducted for all IMI subscales and Total IMI-score.

To test differences in symmetry ratio between the baseline recording, reference VR and the three gaming tasks, a Wilcoxon signed rank test was conducted. The symmetry ratio for the baseline recording was used as a reference, to which the symmetry ratio for the reference VR and the three different gaming tasks were compared to.

To see whether there was a correlation between motivation and changes in gait symmetry, a Spearman correlation test was performed for all three gaming tasks. Symmetry ratio for the baseline recording, adjusted symmetry ratio and change in symmetry ratio from the baseline recording to the gaming task were used as symmetry measures. The symmetry measures were correlated with all IMI subscales and Total IMI. Thresholds for interpreting effect size were taken from Cohen's (1988).

Significance level was defined as $p < 0.05$, and trends as $p < 0.1$.

Results

All 10 participants included in the study successfully completed the data collection and were included in further analysis of the data. However, results from one of the questions from the Interest/enjoyment subscale was missing for one participant on the Hit Tiles task. The demographics and baseline clinical characteristics for all participants are shown in Table 2.

Table 2. Number of males/females, type of stroke, side of lesion, experience with treadmill and VR, and median and interquartile range (IQR) for age, height, weight, and time since stroke for all participants.

Sex (m/f)	7/3
Age [yrs] (median (IQR))	64 (55.7-65.7)
Height [cm] (median (IQR))	175.2 (161.8-179.8)
Weight [kg] (median (IQR))	74 (64.6-84.7)
Ischemic/hemorrhagic stroke	4/6
Side of lesion (left/right)	3/7
Time since stroke [months] (median (IQR))	66 (31-112.5)
Experience with treadmill (yes/no)	10/0
Experience with VR (yes/no)	2/8

IMI

Total IMI-score

As can be seen in Figure 5, almost all participants scored consistently high on Total IMI-score on all three tasks, with a range between 4.8 and 7 on a scale between 1 and 7. Exceptions from this overall pattern were two participants who scored lower on the Cognitive Motor Task (2 and 5), while one participant scored the Cognitive Motor Task higher than the other two tasks (4). Furthermore, one participant (3) scored lower on Hit Tiles task compared to the other two tasks. The small variations between participants and tasks regarding Total IMI-score were reflected in a Wilcoxon Signed Ranked Test showing no significant differences between the three gaming tasks (all p’s>0.2).

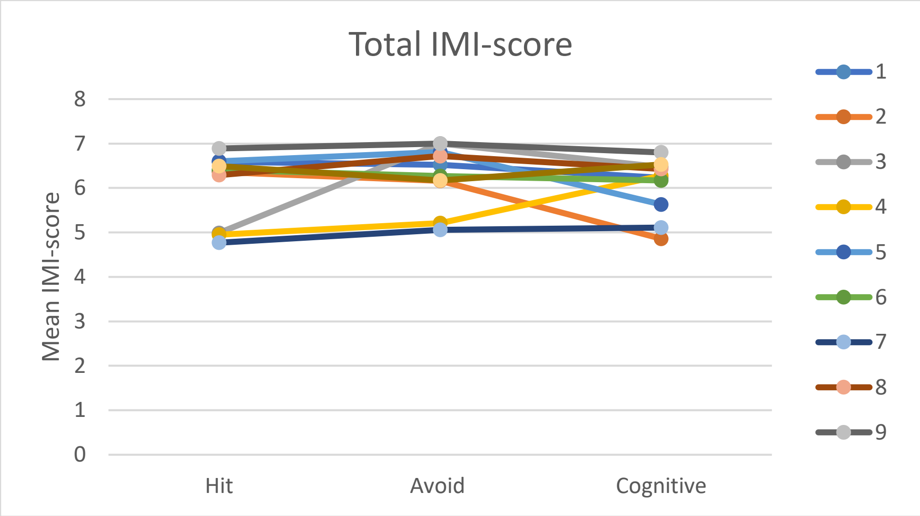


Figure 5. Mean Total IMI score on all three gaming tasks for all participants.

Interest/enjoyment

As can be seen in Figure 6, participants scored high on the Interest/enjoyment subscale on all three tasks. However, there were some individual exceptions. Two participants (2 and 5) scored lower on the Cognitive Motor Task, while one participant (4) scored higher on the Cognitive Motor Task higher compared to the other two tasks. This participant also scored the Avoid Strips Task lower than the two other tasks on the Interest/enjoyment subscale. However, none of these differences were significant (all p's>0.5).

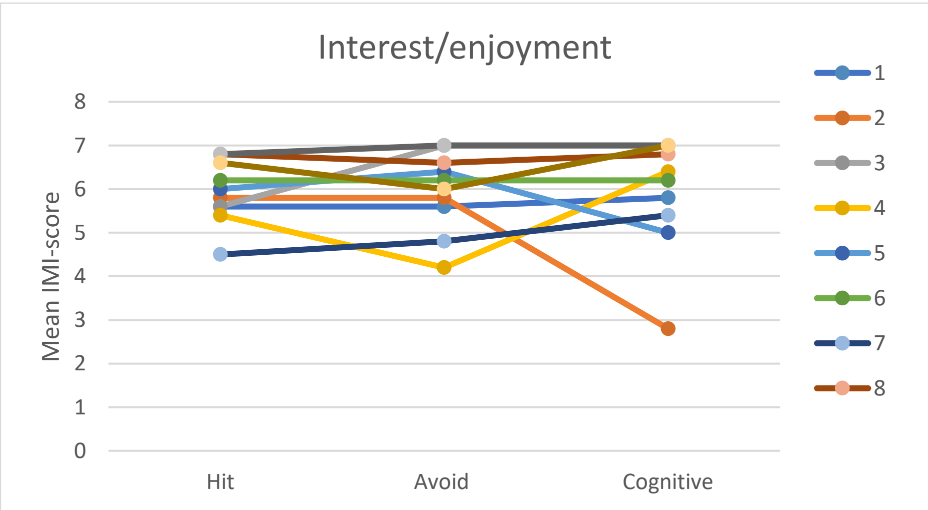


Figure 6. Mean IMI score on the Interest/enjoyment subscale on all three gaming tasks for all participants.

Perceived competence

As can be seen in Figure 7, the participants scored generally high on the Perceived competence subscale. However, the scores differed between gaming tasks. Participants scored lower on the Cognitive Motor task compared to the Avoid Strips Task, and this difference was significant (p=0.007). Participants also tended to score higher on the Avoid Strips Task compared to the Hit Tiles Task, but the difference did not reach significance ($p=0.064$). Participants seem to score the Hit Tiles Task higher than the Cognitive Motor Task, but this difference was not significant ($p>0.2$). There were some individual variations from this overall pattern, for example one participant scored the Cognitive Motor task higher than the Avoid Strips task, and two participants scored substantially lower compared to the other participants in some of the tasks.

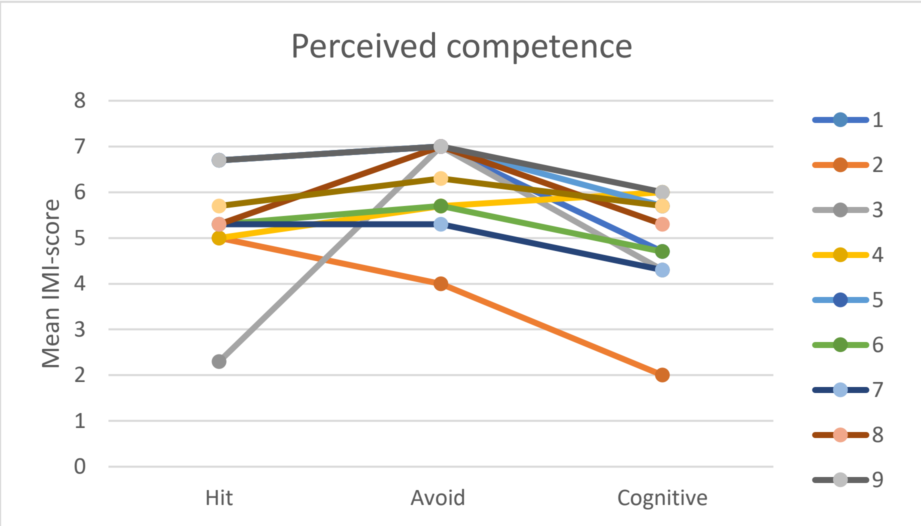


Figure 7. Mean IMI score on the Perceived competence subscale on all three gaming tasks for all participants.

Effort/importance

As can be seen in Figure 8, participants scored generally high on the Effort/importance subscale on all three tasks. However, there were some individual variations from this overall pattern. One participant (4) scored higher on the Cognitive Motor Task compared to the other two tasks, whereas another participant (7) scored lower on all three tasks compared to the other participants. However, there was no significant difference between any of the tasks (all p’s >0.1)

Figure 8. Mean IMI score on the Effort/importance subscale for all three gaming tasks for all participants.

Pressure/tension

As can be seen in Figure 9, participants generally scored high on the Pressure/tension subscale on all gaming tasks (high scores indicate relatively low experienced Pressure/ tension). However, one participant (3) scored substantially lower on the Hit Tiles task compared to the other two tasks. A Wilcoxon signed rank test showed that none of the differences between gaming tasks was significant (all p's >0.1).

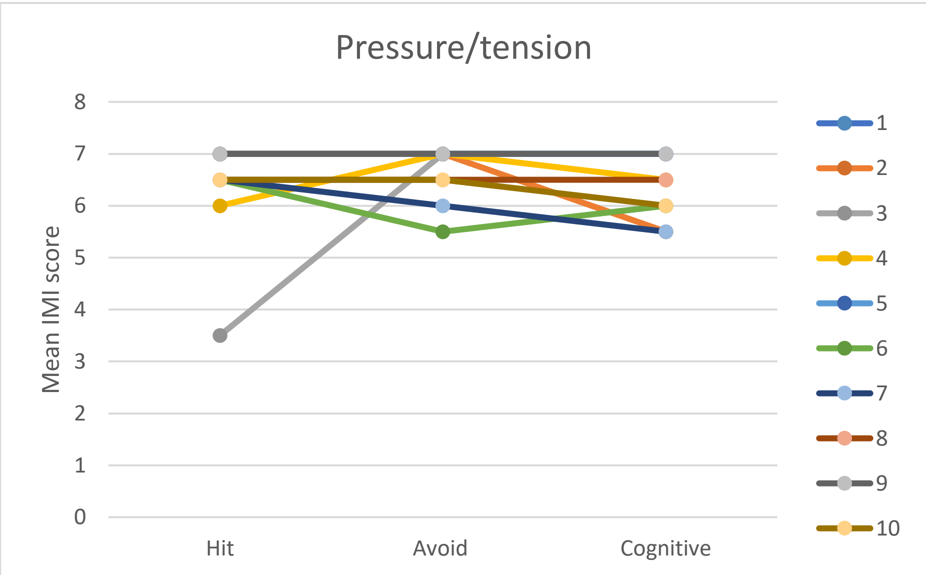


Figure 9. Mean IMI score on the Pressure/tension subscale for all three gaming tasks for all participants.

Value/usefulness

As can be seen in Figure 10, most participants scored high on the Value/usefulness subscale in all tasks. However, there were some individual variations. Two participants scored lower on the Hit Tiles task compared to Avoid Strips task. Three participants (4, 7 and 10) scored higher on the Cognitive Motor task compared to the Avoid Strips task, while one participant

(5) scored lower on the Cognitive Motor task compared to the Avoid Strips task. However, none of the differences between the gaming tasks reached significance (all p's>0.4).

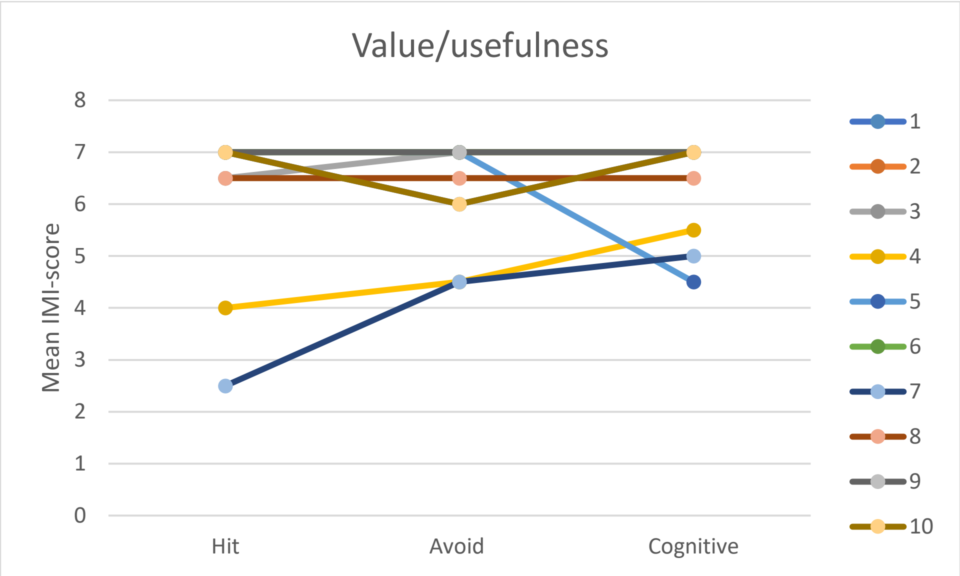


Figure 10. Mean IMI score on the Value/usefulness subscale for all three gaming tasks for all participants.

Additional questions

Results from the additional motivation questions (question 1-3, see Table 3) revealed that most participants liked the Cognitive Motor task the best and found this most motivating. Only one participant preferred the Avoid Strips task best and found this task most motivating. Generally, participants did not find any of the tasks too difficult, but one participant answered that the Hit Tiles task and one that the Cognitive Motor task was too difficult. When asked what part of the training situation had the biggest impact on their motivation, two of the participants gave multiple answers while the other participants gave only one answer. Four answered the feedback from the game, three participants answered to be in a VR-world, five participants answered the gaming elements and one participant answered that the feeling of control in the game had the biggest impact.

Table 3. Results on the additional questions (1-3) for all participants.

	Hit Tiles task	Avoid Strips task	Cognitive Motor Task	None
Liked the most	4	1	5	0
Most motivating	3	1	6	0
Too difficult	1	0	1	8

In short, results on motivation show that participants scored high on all three gaming tasks on most of the IMI subscales. Only on the Perceived competence subscale, scores differed significantly between gaming tasks. According to the additional questions, participants liked the Cognitive Motor task best, and found this more motivating. The part of the training situation yielding the highest impact on motivation differed between participants.

Step Length Symmetry

As can be seen in Table 4, participants walked with differences in speed, thus yielding differences in distance walked and maximum adjustment. Lowest adjustment was around 14 % on all three gaming tasks, and highest adjustment around 45 % on all three gaming tasks, resulting in large variations in amount of maximum adjustment between participants.

Figure 11 shows individual results on symmetry ratio for the baseline recording, reference VR and for the three gaming tasks. For most participants, symmetry ratio was closer to 1 (indicating better symmetry) for the reference VR compared to the baseline recording. Furthermore, the symmetry ratio was closer to 1 for the three gaming tasks, but with some individual differences. Participants 1 and 2 seem to have a peak in symmetry ratio for the Hit Tiles task and Avoid Strips task, respectively, but as can be seen in Table 4, this was the first gaming task they performed, and symmetry ratio were closer to 1 for the subsequent task. No participants seem to have a peak in symmetry ratio for the Cognitive Motor task.

The pattern in Figure 11 is supported by descriptive statistics and Wilcoxon signed rank test (see Table 5), where the symmetry ratio for the reference VR and the three gaming tasks was compared to the symmetry ratio for the baseline recording. As can be seen in the table, the symmetry ratio for the reference VR was not significantly different from the baseline recording. For the three gaming tasks the symmetry ratio is closer to 1, with similar values across tasks, but with differences in variation, reflected in Figure 11. However, the differences from the baseline recording were small, and the difference in symmetry ratio for the Hit Tiles task and Cognitive Motor task was not significant (p’s >0.1). The symmetry ratio for the Avoid Strips task was closer to the significance level (p=0.09).

Table 4. First gaming task, walking speed on treadmill, distance walked and maximum adjustment of tiles/strips on all three gaming tasks for all participants.

Participant	**First task**	**Walking speed treadmill (km/t)**	**Adjustment tiles in % (distance, m)**	**Adjustment strips in % (distance, m)**	**Adjustment tiles on cognitive in % (distance, m)**
1	Tiles	2.0	22.6 (86.0)	22.1 (84.0)	21.8 (82.8)
2	Strips	2.3	21.8 (83.0)	24.2 (92.0)	26.5 (100.6)
3	Tiles	1.5	16.6 (63.0)	15.9 (60.6)	16.5 (62.6)
4	Strips	4.0	44.2 (167.8)	45.8 (173.9)	46.4 (176.1)
5	Tiles	2.0	21.9 (83.2)	21.4 (81.5)	23.7 (90.2)
6	Strips	1.3	14.0 (53.3)	13.9 (52.8)	13.9 (52.8)
7	Tiles	3.0	37.2 (141.2)	37.1 (141.0)	36.2 (137.6)
8	Strips	3.5	39.5 (150.1)	40.6 (154.3)	40.0 (152.1)
9	Tiles	2.3	26.8 (101.8)	26.7 (101.4)	28.7 (109.0)
10	Strips	3.5	41.3 (156.8)	38.6 (146.7)	41.9 (159.2)

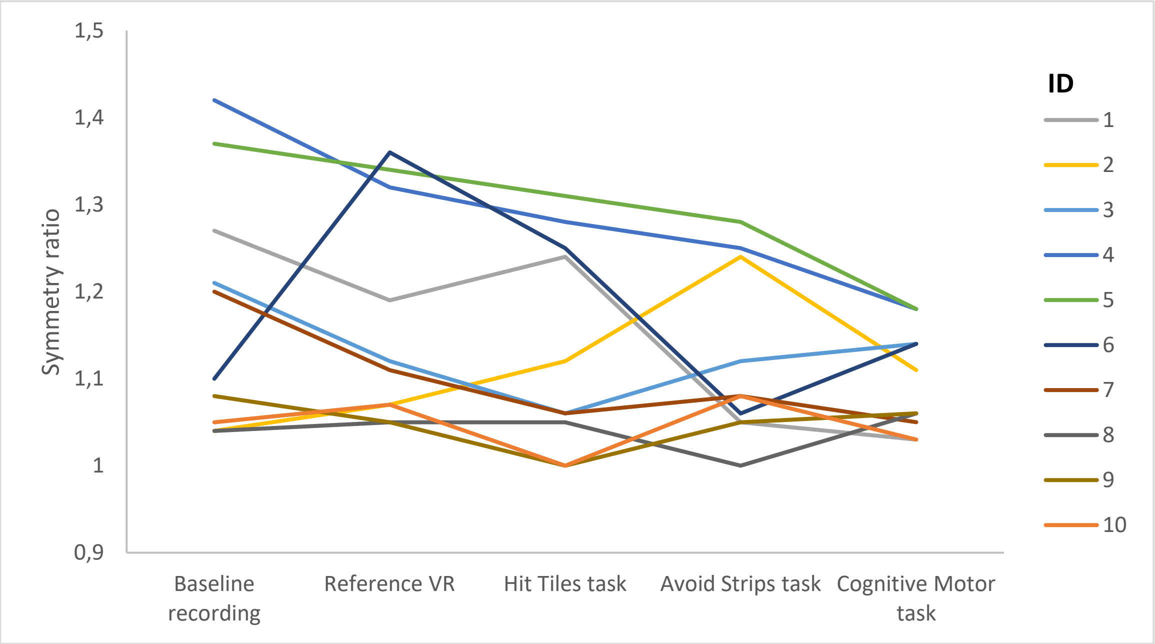


Figure 11. Symmetry ratio for the baseline recording, reference VR and the three gaming tasks for each participant.

Table 5. Median step length (cm) and symmetry ratio with interquartile range. Z-value and p-value from the Wilcoxon signed rank test, comparing reference VR and the three gaming tasks to the baseline recording.

	Left (IQR)	Right (IQR)	Symmetry ratio (IQR)	Difference symmetry ratio	
Baseline	45.2 (34.8-48.1)	46.6 (35.3-55.7)	1.15 (1.05-1.29)	z	*p*
Reference VR	46.4 (37.3- 48.4)	47.9 (39-53.7)	1.11(1.06-1.32)	-0.97	0.33
Hit Tiles task	49.1 (38.2-53.5)	49.6 (28.5-57.1)	1.09 (1.04-1.26)	-1.17	0.24
Avoid Strips task	45.4 (39.8-51.6)	48.4 (34.2-56.7)	1.08 (1.05-1.24)	-1.68	0.09
Cognitive Motor task	48.3 (37.8-53.3)	47.6 (37.5-56.6)	1.08 (1.05-1.15)	-1.58	0.11

In short, the symmetry ratio for the reference VR was slightly closer to 1 compared to the baseline recording, but not significantly different. The symmetry ratio for the three gaming tasks were closer to 1 across tasks as well, but not significantly different from the baseline recording either.

Relation between motivation and symmetry ratio

To examine the potential correlation between motivation and changes in symmetry, a Spearman correlation analysis was done between all IMI scores and all symmetry measures. As can be seen in Table 6, the results for the Hit Tiles task showed that symmetry was negatively correlated with motivation. There was a moderate correlation (r=-0.6) with symmetry ratio for the baseline recording and the score on the Interest enjoyment subscale, which was also significant (p=0.04). The change in symmetry ratio also tended to correlate with score on the Value/usefulness subscale (r=-0.61, p=0.06). However, from visual inspection of the scatterplot (see Figure 12), where positive values indicate improvements in symmetry, while negative values indicate deterioration in symmetry, the relationship did not appear to be linear. Most of the participants scored high on the Value/usefulness subscale, seemingly independent of improvements in symmetry. The remaining participants differed in score on the Value/usefulness subscale but improved greatly in symmetry. There seemed to be no clear correlation between any of the other subscales or symmetry measures for the Hit Tiles task (all p's>0.1).

For the Avoid Strips task (see Table 7) there seemed to be no clear correlation between any of the subscales or symmetry measures (all p's >0.1). For the Cognitive Motor task (see Table 8) the change in symmetry ratio correlated negatively with the score on Effort/importance subscale (r=-0.59). However, from visual inspection of the scatterplot (see Figure 13), the relation did not seem linear. For 3 of the participants, there seemed to be a trend towards a positive relation between change in symmetry and score on the Effort/importance subscale. The remaining participants scored high on motivation independent of change in symmetry. There were no clear correlations between any of the other subscales and symmetry measures for the Cognitive Motor task (all p's>0.1).

Table 6. Correlations between baseline symmetry, adjusted symmetry and change in symmetry with IMI subscales and Total IMI on the Hit Tiles task. Low correlation coefficients between -0.3 and 0.3 are removed. Grey negative correlation. Strength of the color indicates how strong the correlation is. Statistically significant correlations are in red.

Hit Tiles task	Baseline symmetry	Adjusted symmetry	Change in symmetry
Interest/enjoyment	**-0.65**	-0.45	-0.47
Perceived competence			
Effort/importance	-0.40		
Pressure/tension			-0.49
Value/usefulness			**-0.61**
Total IMI			-0.37

Table 7. Correlations between baseline symmetry, adjusted symmetry and change in symmetry with IMI subscales and Total IMI on the Avoid Strips task. Low correlation coefficients between -0.3 and 0.3 are removed. Green indicates positive correlation, grey negative correlation. Strength of the color indicates how strong the correlation is. None of the correlations were statistically significant.

Avoid strips task	Baseline symmetry	Adjusted symmetry	Change in symmetry
Interest/enjoyment	-0.34		-0.42
Perceived competence		-0.36	
Effort/importance	-0.42	-0.51	-0.30
Pressure/tension	0.39	0.37	
Value/usefulness			-0.51
Total IMI			

Table 8. Correlations between baseline symmetry, adjusted symmetry and change in symmetry with IMI subscales and Total IMI on the Cognitive Motor task. Low correlation coefficients between -0.3 and 0.3 are removed. Green indicates positive correlation, grey negative correlation. Strength of the color indicates how strong the correlation is. None of the correlations were statistically significant.

Cognitive Motor task	Baseline symmetry	Adjusted symmetry	Change in symmetry
Interest/enjoyment			
Perceived competence			
Effort/importance	-0.45		-0.59
Pressure/tension	0.45		0.48
Value/usefulness	-0.41	-0.40	-0.43
Total IMI			

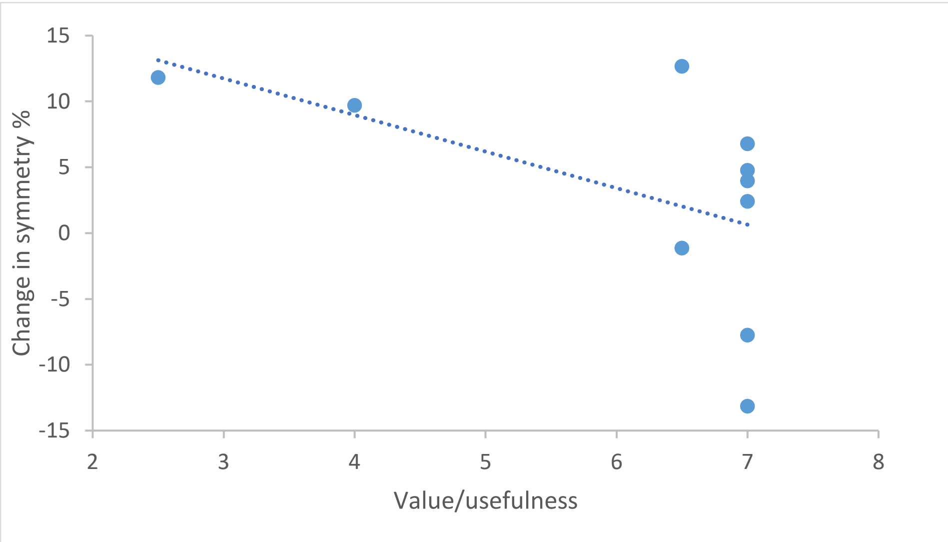


Figure 12. Scatterplot between score on the Value/usefulness subscale and change in symmetry on the Hit Tiles task.

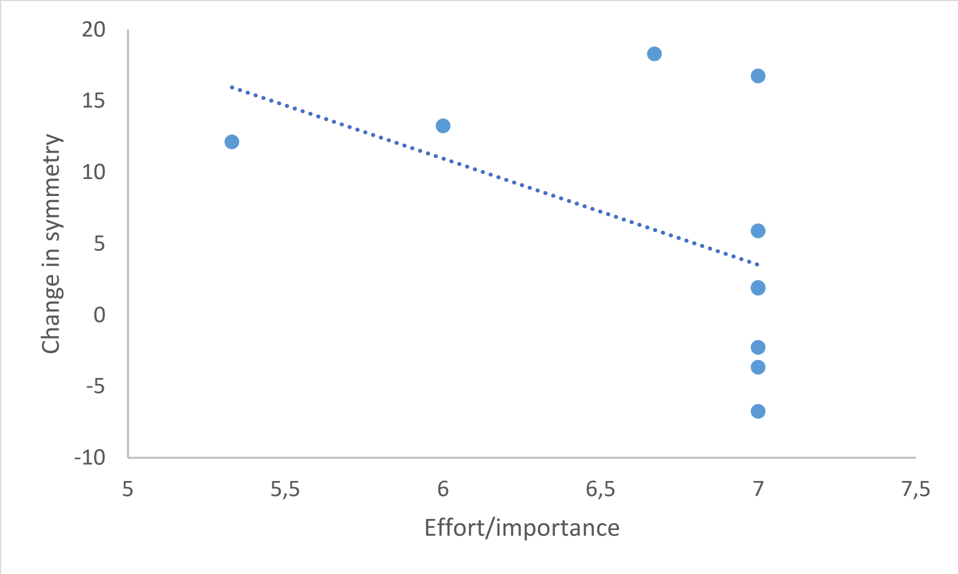


Figure 13. Scatterplot between score on the Effort/importance subscale and change in symmetry on the Cognitive Motor task.

Discussion

The main research question addressed in this paper was whether different gaming tasks in a VR-gait training game affected motivation and gait symmetry in stroke patients. A second research questions was whether there was a correlation between motivation and changes in gait symmetry. Ten stroke patients in subacute or chronic phase played a single gait training session with three different gaming tasks. Motivation and step length symmetry were measured, and motivation scores compared across tasks, while step length symmetry ratio was compared between baseline gait pattern and gait pattern during the last steps in each gaming task with maximum adjustment. Finally, the results on motivation and symmetry were correlated to examine potential relationships between the two.

Below, results on motivation, symmetry and their correlation are discussed, as are possible interpretations of the results and how this corresponds with previous research studies. Then the focus will turn to strengths and weaknesses of this paper. Finally, some directions for further research are given.

Motivation in the different gaming tasks.

Motivation results show generally high motivation scores on Total IMI and all IMI subscales on all three gaming tasks. This indicates that the participants found all three gaming tasks interesting/enjoyable, they felt relatively competent, little pressured, gave equal effort, and found all the gaming tasks equally valuable and useful. The high motivation scores are in accordance with other VR-studies using IMI in stroke patients (Bergmann et al., 2018; Lloréns, Noé, Colomer, & Alcañiz, 2015; Prange et al., 2015; Sampson, Shau, & James king, 2012; Subramanian et al., 2013). These results indicate that participants are highly motivated when playing the game, seemingly independent of gaming tasks. This is a promising result that encourages further research on this type of VR-game. However, the participants only played a single gait training session, while traditional rehabilitation programs often continue for several months with frequent weekly training sessions. Thus, it is uncertain whether the immediate positive motivation scores shown in this study will be maintained in interventions of longer duration. This is an important topic for future research.

The high motivation scores across tasks were present on almost all subscales. Only on the Perceived competence subscale, the scores differed across tasks, and indicated that participants felt less competent while playing the Cognitive Motor task. This may be caused by the abrupt increase in difficulty level in the Cognitive Motor task, which may have led to a mismatch between the participants' skill level and the requirements of the task (Woodbury et al., 2016). Furthermore, the participants tended to feel more competent while playing the Avoid Strips task compared to the Hit Tiles task. However, this may be related to some technical difficulties with the feedback from the game on the Avoid Strips task. More specifically, the game did not always register the feet placement correctly in some of the participants, giving an overestimation of percentage score on each foot. This may have given these participants the impression of performing better than they actually were.

No clear tendency of differences between gaming tasks was shown in any of the other subscales. To our knowledge, this is the first study measuring motivation in different gait specific tasks, making it difficult to draw comparisons with existing literature on previous studies. Nevertheless, discussion of additional questions, possible reasons for the results, and what we can learn from individual differences follows to guide further research directions.

Despite participants feeling less competent on the Cognitive Motor task, the results on the Interest/enjoyment subscale revealed that participants found the Cognitive Motor task equally or more interesting/enjoyable compared to the other tasks. Also, according to the results on the additional questions, the Cognitive Motor task was reported as best liked and the most motivating task. This result is in accordance with results from a previous study on elderly (Skjæret-Maroni et al., 2016), where participants found adding additional cognitive elements in a stepping-based game to be fun and challenging.

Both the Hit Tiles task and Avoid Strips task were included in the game because of uncertainty whether the participants were more motivated by stepping on objects or stepping over objects, and what kind of instructions would be easier to follow. Results from the IMI show that participants scored high on both Hit Tiles task and Avoid Strips task, with only small differences. However, from the additional questions, participants seem to like better and be more motivated when having to hit objects, compared to avoiding objects. Some participants stated that the narrow strips on the Avoid Strips task were difficult to see and thus to avoid. Therefore, some of the participants performed poorer on this task, possibly making the participants frustrated and less motivated. The tiles on the Hit Tiles task were bigger and thus easier to see and hit. Furthermore, the feedback given through colors on the tiles/strips was less evident on the Avoid Strips task due to the narrow strips, compared to the larger tiles on the Hit Tiles task. The technical difficulties previously mentioned in the Avoid Strips task may also have had a negative impact on the participants' motivation. To our knowledge, there was no such technical difficulties on the Hit Tiles task. Together, this may have influenced why more participants seemed to like the Hit Tiles task better and found this more motivating than the Avoid Strips task.

A common concern when using VR in elderly is that the game may be too demanding in terms of too much colors, moving gaming elements, noise etc. (Skjæret et al., 2016). This is a relevant concern in this study as well, especially considering the demanding gaming interface of the Cognitive Motor task. However, overall results on the Pressure/tension subscale indicated that participants felt little pressured and tense. Also, according to the additional questions, most participants did not find any of the gaming tasks too difficult. One of the participants scored low Pressure/tension on the Hit Tiles task, indicating high experienced Pressure/tension. But, as can be seen in Table 4, the Hit Tiles task was the first gaming task played by this participant, and the score improved in the subsequent tasks. This suggests that with some familiarization to the VR-system, the participant did not experience Pressure/tension anymore. This is in accordance with another study, revealing that participants reported less Pressure/tension with more training (Bergmann et al., 2018). The positive results on the Pressure/tension subscale are a positive indication for the use of this type of intervention in this study population.

Despite the overall positive indication for the use of VR in this study population, there are some individual exceptions in most of the subscales. For example, some participants scored lower on both the Value/usefulness and Effort/importance subscales compared to other participants. This may indicate that when they did not feel that the training was valuable, they did not put in the same effort. This may have been caused by the game not being challenging enough for their physical function (Woodbury et al., 2016). On the other hand, two of the participants scored low on the Perceived competence subscale on the Hit Tiles and Cognitive Motor task and stated in the additional questions that these tasks were too difficult, which might possibly be related to their physical function. Furthermore, according to the additional questions, different participants seem to be motivated by different elements in the training situation, such as being in a VR-world, the feedback given from the game and the gaming elements. Taken together, these results suggest that the same VR game might not most suitable for all participants, and the choice of VR-game in stroke patients must be personalized according to individual needs, function and preferences, which echoes the results in Skjæret-Maroni et al., 2016 (Skjæret-Maroni et al., 2016).

Step length symmetry in the gaming tasks

The results on step length symmetry revealed that there was no significant change in symmetry ratio from when walking without to walking with the VR-headset, indicating that symmetry ratio was not substantially altered when walking with fully immersive VR. This result is in line with another feasibility study, using fully immersive VR on patients with Parkinson’s disease (Kim, Darakjian, & Finley, 2017).

In the three gaming tasks, the symmetry ratio was somewhat closer to 1 than at baseline, suggesting that the game might have potential to improve symmetry in all three gaming tasks if patients would have played longer. This is in line with another feasibility study on a VR gait training game, revealing that stroke patients were able to adapt to tasks in a VR-game (Fung, Richards, Malouin, McFadyen, & Lamontagne, 2006). This is a promising result, encouraging for further implemetation of this type of VR-game in a clinical setting.

When comparing the different gaming tasks to the baseline recording, there were no significant differences in symmetry ratio in any of the gaming tasks, but the differences in symmetry ratio for the Avoid Strips task were somewhat closer to significant (p=0.09) than the Hit Tiles and Cognitive Motor task (p’s >0.01). Thus, in the current study, whether participants had to step on over over objects did not seems to affect symmetry ratio differently.

As can be seen in Table 5, there was a wide range in step length between participants. The use of the symmetry ratio method chosen here gives more room for asymmetry in participants who take longer steps, because of a relatively larger difference in step length between left and right foot. This may be an underlying reason why some of the participants have such a high symmetry ratio (a more asymmetric gait) (see Figure 11), resulting in high between-individual variation across tasks.

Some participants had a peak in symmetry ratio (that is, a more asymmetric gait) in the Hit Tiles task, while others had a peak in the Avoid Strips task, but as mentioned, this might be related to the first gaming task they performed. None of the participants had a peak in the Cognitive Motor task, indicating that symmetry ratio was not negatively affected by the additional cognitive task. If this is indeed the case, this stands in contrast to other studies that found that movement patterns were negatively affected by adding cognitive elements (Bovim et al., 2020; Skjæret-Maroni et al., 2016). But, in the Cognitive Motor task, the participants were instructed to focus on one of the two tasks if they found it too difficult to hit the tiles and find and shoot the specific objects simultaneously. However, no information about the game performance itself was saved in the game, so, it is uncertain whether they focused on both tasks simultaneously, and thus whether the additional cognitive task had a negative impact on gait symmetry or not. Because information about actual game performance were lacking in all tasks, we do not know how well or poorly the participants actually performed on the tasks, that is, if they managed to hit tiles, avoid strips and shoot specific objects. Therefore, it is uncertain whether it was the gaming elements that impacted gait symmetry or other elements in the training situation. For example, some of the participants stated that they were more aware of their gait pattern when being recorded, potentially making them walk differently than they normally would.

Relation between motivation and changes in symmetry

Results from the correlation analysis between motivation and symmetry ratio showed a moderate negative correlation between the symmetry ratio in the baseline recording and score on the Interest/enjoyment subscale on the Hit Tiles task. This indicates that the better the symmetry ratio measured in the baseline recording was, the higher the score was on the Interest/enjoyment subscale. However, the correlation strength was only moderate, and was likely affected by other factors that we did not control for, such as how interested they were in trying the game in the first place.

Although there were some moderate negative correlations between change in symmetry and score on the Value/usefulness subscale on the Hit Tiles task and the score on the Effort/importance subscale on the Cognitive Motor task, the relation did not appear to be linear from visual inspection, and most participants scored high on motivation independent of a change in symmetry. This indicates that participants gave high effort and found the training valuable and useful regardless of change in symmetry.

One would hope to find a positive correlation between change in symmetry and motivation scores, but this was not present in any of the subscales in any of the tasks. However, as can be seen in Figure 13, for 3 participants there might be some indication of a positive correlation between score on the Effort/importance subscale and improvement in symmetry at the Cognitive Motor task, indicating that the higher the effort, the better the improvement. However, this must be regarded with caution, as this only applies to a few participants. The remaining participants scored high on the Effort/importance subscale independent of change in symmetry.

The small variations in motivation scores across tasks and participants, and the small changes in symmetry, make it difficult to draw any conclusions on a potential relationship between motivation and improvements in symmetry. Furthermore, to our knowledge, this is the first study examining the correlation between motivation and motor outcome, making it hard to compare with other studies. The studies that have described a relationship between motivation and motor learning, have stated that higher motivation leads to better motor learning indirectly through more repetitive movements and training time, thereby facilitating neuroplasticity and enhanced functional movements (Rohrbach et al., 2019). In other words, one could say that motivation leads to better adherence to a training program, which in turn may lead to better motor learning. In this study, only the immediate impact of gait training task on motivation and symmetry were studied. Thus, a longer intervention, possibly performed at home, where participants themselves decide training duration, is needed to confirm this relationship.

Strengths and weaknesses

A major strength of this study is the use of a validated standardized questionnaire to measure motivation. The questionnaire used is designed to measure motivation, a consistency often lacking in other VR-studies (Rohrbach et al., 2019). The use of a standardized questionnaire allows for comparison of results with existing literature.

However, the use of a questionnaire to measure motivation brings several limitations as well. Firstly, the IMI-questionnaire has not been validated in Norwegian, only in English, thus giving some uncertainty about the validity of the questionnaire responses. However, a standardized Norwegian questionnaire measuring motivation is lacking. Therefore, because the IMI-questionnaire has been validated in stroke patients (Colombo et al., 2007) and is the most frequently used measure in VR-interventions for stroke patients (Rohrbach et al., 2019), this was considered the best option. The questionnaire was translated with the purpose of keeping the substance in the original questions, tested on 14 pilots and adjusted according to their feedback, before being used in the current study.

Secondly, the intrinsic nature of the IMI might be less suitable for measuring the immediate effect on motivation. Motivation when trying something new can be affected by more than just intrinsic motivation, for example how extrinsically motivated they are from rewards or from being part of an research study (Ryan & Deci, 2000). Furthermore, the users' experiences and responses to the same VR- technology can differ greatly between personalities (Kober & Neuper, 2013). Also, previous research has raised concerns whether there might be a problem with self-assessment and speech comprehension in this study population (Bergmann et al., 2018; Prange et al., 2015). To attempt to avoid this problem the questions was read aloud by a member of the project group, and smiley faces recommended by a speech therapists was used on the Likert scale (see Appendix 1). However, complete removal of the problem was difficult to control for.

Finally, the use of a questionnaire with a Likert scale gives the possibility of a ceiling effect, considering that the highest value on the scale is 7. The participants in this study scored generally high on all subscales, but relatively few participants scored 7 on all subscales and tasks. The ceiling effect in some of the participants may be caused by the participants being aware of participating in a research projects and wanting to give positive results. Furthermore, because the questions were read aloud, and answers were collected by a member of the project group, it might have been more difficult to answer as honest and critical as possible. Furthermore, we cannot exclude the possibility of selection bias, given that the participants participated voluntarily and might have been highly motivated to try the game in the first place. Thus, the high motivation level in this study population might not be generalized to other stroke patients. Nevertheless, high motivation scores are shown in several VR-intervention studies, with a variety of stroke patients.

Another important strength of this study was the game used, consisting of specific gait training tasks, with the possibility to add an additional Cognitive Motor task through gaming elements. Furthermore, the game provided a unique opportunity to personalize the training according to the participants' physical function, by placing the tiles/strips dependent on their individual gait pattern. The difficulty level was gradually increased by adjustment of the tiles/strips, and the participants were given immediate feedback on their performance. This likely results in a fun and motivational way to train gait, personalized to physical function and with the possibility to track performance. Motivational aspects were measured in a standardized way after each gaming task, making it possible to examine how the different gaming tasks affected motivation. Furthermore, the walking speed was equal on all recordings, making it possible to compare the different recordings and examine how different gaming tasks affected gait pattern, independent of gait speed.

However, the game was still a prototype when used in the data collection, which gave some technical difficulties along the way. For example, there were some technical problems with the tracking of foot placement, leading to an overestimation of the feedback on performance given from the game, which may have influenced the motivation scores. Furthermore, no information about performance in the game was saved. This makes it difficult to draw conclusions whether the participants were able to hit/avoid the lists/strips or shoot the specific objects, and what elements in the training situation affected symmetry.

The main weakness in the study was the short amount of time each participant walked on the treadmill, making it difficult to find clear results on symmetry changes. The total amount of adjustment was dependent on walking speed. As the latter varied greatly between participants, so did the amount of adjustment achieved. Thus, participants with lowest speed received the lowest relative amount of adjustment, while participants with the highest speed received the highest relative amount of adjustment. Given that gait speed is correlated with physical function (Cesari, 2011), this should have been the other way around, as participants with the weakest physical function are the ones most in need of training. This way of adjusting gait pattern was chosen because we did not know the physical function of the participants in advance and had to choose a time-efficient alternative considering the limited time frame. As a further disadvantage, no clear guidelines on how to adjust gait pattern in a VR-game are present in existing literature.

Finally, non-parametric tests had to be used because none of the variables could be considered normally distributed. A larger sample size could have allowed for the use of parametric tests, thereby increasing the power in the statistical analyses.

Further research

The high motivation scores across tasks found in this study are promising and encourage the further use of this type of technology in research on stroke rehabilitation. However, only immediate effects were studied, and little is known about the short and long-term effects of this type of intervention on motivation. This is an important topic for further research. Further research should also develop better measures for motivation that can account for the complex nature of motivation and the possible problems with self-assessment and speech comprehension in stroke patients.

Furthermore, further research on this type of VR-games should find a way to ensure 100 % adjustment for all participants during a trial, making it possible to compare improvements in symmetry across participants. This can be done by expanding the time frame participants play the game. However, the expended time frame may possibly exclude participants who are not able to walk on a treadmill for the required time needed to reach 100 % adjustment. Thus, participants with a low physical function might be excluded from participation in such a research project. Furthermore, before implementing this type of technology in a rehabilitation setting, all technical aspects have to perform together to avoid a negative influence on the results. Together, this may give a better picture of how the different gaming tasks affect motivation and symmetry.

With a better measure of motivation in interventions of longer duration and a clearer picture of the gaming tasks' impact on gait pattern, it would be more possible to find clearer results and draw conclusions on the potential relation between motivation and improvements in symmetry. Armed with such knowledge, a clinical trial could be designed to evaluate the effect of a VR-gait training game on gait-related functions during a longer intervention period.

Conclusion

The results from this study reveal that stroke patients scored generally high on all IMI-subscales across different gaming tasks. Only on the Perceived/competence subscale participants scored lower when adding an additional Cognitive Motor task. The high motivation scores are promising results, encouraging more research on this type of intervention. Furthermore, the gaming tasks seem to have the potential to improve gait asymmetry towards are more symmetrical gait, although from the current study, it cannot be deduced whether this could differ between tasks. Conclusions are even more difficult to draw regarding the relationship between motivation and improvements in symmetry, because of small variations in motivation across tasks and small changes in symmetry. Further research should develop a better measure for motivation and use this in interventions of longer durations, ensure equal adjustment of gait symmetry and exclude technical problems.

References

Bergmann, J., Krewer, C., Bauer, P., Koenig, A., Riener, R., & Muller, F. (2018). Virtual reality to augment robot-assisted gait training in non-ambulatory patients with a subacute stroke: a pilot randomized controlled trial. *Eur J Phys Rehabil Med, 54*(3), 397-407. doi:10.23736/s1973-9087.17.04735-9

Bohannon, R. W., Andrews, A. W., & Smith, M. B. (1988). Rehabilitation goals of patients with hemiplegia. *International Journal of Rehabilitation Research, 11*(2), 181-184. Retrieved from https://journals.lww.com/intjrehabilres/Fulltext/1988/06000/Rehabilitation_goals_of_patients_with_hemiplegia.12.aspx

Bovim, L. P., Gjesdal, B. E., Mæland, S., Aaslund, M. K., & Bogen, B. (2020). The impact of motor task and environmental constraints on gait patterns during treadmill walking in a fully immersive virtual environment. *Gait & Posture, 77*, 243-249. doi:https://doi.org/10.1016/j.gaitpost.2020.01.031

Cesari, M. (2011). Role of Gait Speed in the Assessment of Older Patients. *JAMA, 305*(1), 93-94. doi:10.1001/jama.2010.1970

Colombo, R., Pisano, F., Mazzone, A., Delconte, C., Micera, S., Carrozza, M. C., . . . Minuco, G. (2007). Design strategies to improve patient motivation during robot-aided rehabilitation. *J Neuroeng Rehabil, 4*, 3. doi:10.1186/1743-0003-4-3

Dam, M., Tonin, P., Casson, S., Ermani, M., Pizzolato, G., Iaia, V., & Battistin, L. (1993). The effects of long-term rehabilitation therapy on poststroke hemiplegic patients. *Stroke, 24*(8), 1186-1191.

Darekar, A., McFadyen, B. J., Lamontagne, A., & Fung, J. (2015). Efficacy of virtual reality-based intervention on balance and mobility disorders post-stroke: a scoping review. *J Neuroeng Rehabil, 12*, 46. doi:10.1186/s12984-015-0035-3

de Rooij, I. J., van de Port, I. G., & Meijer, J. G. (2016). Effect of Virtual Reality Training on Balance and Gait Ability in Patients With Stroke: Systematic Review and Meta-Analysis. *Phys Ther, 96*(12), 1905-1918. doi:10.2522/ptj.20160054

Deci, E. L., Eghrari, H., Patrick, B. C., & Leone, D. R. (1994). Facilitating internalization: The self-determination theory perspective. *Journal of personality, 62*(1), 119-142.

Endresen, M. (2019). *Det var jo fryktelig artig da å være i en sånn VR-verden …*.

Feigin, V. L., Nichols, E., Alam, T., Bannick, M. S., Beghi, E., Blake, N., . . . Ellenbogen, R. G. (2019). Global, regional, and national burden of neurological disorders, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. *The Lancet Neurology, 18*(5), 459-480.

Flansbjer, U.-B., Downham, D., & Lexell, J. (2006). Knee muscle strength, gait performance, and perceived participation after stroke. *Arch Phys Med Rehabil, 87*(7), 974-980.

Fung, J., Richards, C. L., Malouin, F., McFadyen, B. J., & Lamontagne, A. (2006). A treadmill and motion coupled virtual reality system for gait training post-stroke. *CyberPsychology & Behavior, 9*(2), 157-162.

Gamboa, E., Ruiz, C., & Trujillo, M. (2018). *Improving Patient Motivation Towards Physical Rehabilitation Treatments with PlayTherapy Exergame.* Paper presented at the pHealth.

GBD Lifetime Risk of Stroke Collaborators. (2018). Global, regional, and country-specific lifetime risks of stroke, 1990 and 2016. *New England Journal of Medicine, 379*(25), 2429-2437.

Gibbons, E. M., Thomson, A. N., de Noronha, M., & Joseph, S. (2016). Are virtual reality technologies effective in improving lower limb outcomes for patients following stroke - a

systematic review with meta-analysis. *Top Stroke Rehabil, 23*(6), 440-457. doi:10.1080/10749357.2016.1183349
Guo, R., Samaraweera, G., & Quarles, J. (2013). *The effects of VEs on mobility impaired users: Presence, gait, and physiological response.* Paper presented at the Proceedings of the 19th ACM Symposium on Virtual Reality Software and Technology.
Hesse, S. (2008). Treadmill training with partial body weight support after stroke: a review. *NeuroRehabilitation, 23*(1), 55-65.
Jung, J., Yu, J., & Kang, H. (2012). Effects of Virtual Reality Treadmill Training on Balance and Balance Self-efficacy in Stroke Patients with a History of Falling. *Journal of Physical Therapy Science, 24*(11), 1133-1136. doi:10.1589/jpts.24.1133
Jørgensen, H. S., Nakayama, H., Raaschou, H. O., & Olsen, T. S. (1995). Recovery of walking function in stroke patients: the Copenhagen Stroke Study. *Arch Phys Med Rehabil, 76*(1), 27-32.
Karpman, C., LeBrasseur, N. K., DePew, Z. S., Novotny, P. J., & Benzo, R. P. (2014). Measuring gait speed in the out-patient clinic: methodology and feasibility. *Respiratory care, 59*(4), 531-537.
Kim, A., Darakjian, N., & Finley, J. M. (2017). Walking in fully immersive virtual environments: an evaluation of potential adverse effects in older adults and individuals with Parkinson's disease. *J Neuroeng Rehabil, 14*(1), 16.
Kober, S. E., & Neuper, C. (2013). Personality and Presence in Virtual Reality: Does Their Relationship Depend on the Used Presence Measure? *International Journal of Human–Computer Interaction, 29*(1), 13-25. doi:10.1080/10447318.2012.668131
Laver, K. E., Lange, B., George, S., Deutsch, J. E., Saposnik, G., & Crotty, M. (2017). Virtual reality for stroke rehabilitation. *Cochrane database of systematic reviews*(11).
Lincoln, N. B., Jackson, J. M., & Adams, S. A. (1998). Reliability and Revision of the Nottingham Sensory Assessment for Stroke Patients. *Physiotherapy, 84*(8), 358-365. doi:https://doi.org/10.1016/S0031-9406(05)61454-X
Lloréns, R., Noé, E., Colomer, C., & Alcañiz, M. (2015). Effectiveness, usability, and cost-benefit of a virtual reality–based telerehabilitation program for balance recovery after stroke: A randomized controlled trial. *Arch Phys Med Rehabil, 96*(3), 418-425. e412.
Luque-Moreno, C., Ferragut-Garcias, A., Rodriguez-Blanco, C., Heredia-Rizo, A. M., Oliva-Pascual-Vaca, J., Kiper, P., & Oliva-Pascual-Vaca, A. (2015). A Decade of Progress Using Virtual Reality for Poststroke Lower Extremity Rehabilitation: Systematic Review of the Intervention Methods. *Biomed Res Int, 2015*, 342529. doi:10.1155/2015/342529
Macko, R. F., Haeuber, E., Shaughnessy, M., Coleman, K. L., Boone, D. A., Smith, G. V., & SILVER, K. H. (2002). Microprocessor-based ambulatory activity monitoring in stroke patients. *Medicine & Science in Sports & Exercise, 34*(3), 394-399.
McAuley, E., Duncan, T., & Tammen, V. V. (1989). Psychometric properties of the Intrinsic Motivation Inventory in a competitive sport setting: A confirmatory factor analysis. *Research quarterly for exercise and sport, 60*(1), 48-58.
Meldrum, D., Herdman, S., Vance, R., Murray, D., Malone, K., Duffy, D., . . . McConn-Walsh, R. (2015). Effectiveness of conventional versus virtual reality–based balance exercises in vestibular rehabilitation for unilateral peripheral vestibular loss: results of a randomized controlled trial. *Arch Phys Med Rehabil, 96*(7), 1319-1328. e1311.
Miller, E. L., Murray, L., Richards, L., Zorowitz, R. D., Bakas, T., Clark, P., & Billinger, S. A. (2010). Comprehensive overview of nursing and interdisciplinary rehabilitation care of the stroke patient: a scientific statement from the American Heart Association. *Stroke, 41*(10), 2402-2448.
Patel, M. D., Tilling, K., Lawrence, E., Rudd, A. G., Wolfe, C. D., & McKevitt, C. (2006). Relationships between long-term stroke disability, handicap and health-related quality of life. *Age Ageing, 35*(3), 273-279. doi:10.1093/ageing/afj074
Patterson, K. K., Gage, W. H., Brooks, D., Black, S. E., & McIlroy, W. E. (2010). Evaluation of gait symmetry after stroke: A comparison of current methods and recommendations for standardization. *Gait & Posture, 31*(2), 241-246. doi:https://doi.org/10.1016/j.gaitpost.2009.10.014

Prange, G. B., Kottink, A. I., Buurke, J. H., Eckhardt, M. M., van Keulen-Rouweler, B. J., Ribbers, G. M., & Rietman, J. S. (2015). The effect of arm support combined with rehabilitation games on upper-extremity function in subacute stroke: a randomized controlled trial. *Neurorehabil Neural Repair, 29*(2), 174-182.

Påsche Sørenmo, A. (2019). Virtual Reality i tredemølle-basert rehabilitering.

Rohrbach, N., Chicklis, E., & Levac, D. E. (2019). What is the impact of user affect on motor learning in virtual environments after stroke? A scoping review. *J Neuroeng Rehabil, 16*(1), 79. doi:10.1186/s12984-019-0546-4

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American psychologist, 55*(1), 68.

Sampson, M., Shau, Y.-w., & James king, M. (2012). Bilateral upper limb trainer with virtual reality for post-stroke rehabilitation: case series report. *Disability and Rehabilitation: Assistive Technology, 7*(1), 55-62.

Self-Determination Theory. (2019). Intrinsic Motivation Inventory (IMI). Retrieved from https://selfdeterminationtheory.org/intrinsic-motivation-inventory/

Skjæret-Maroni, N., Vonstad, E. K., Ihlen, E. A., Tan, X.-C., Helbostad, J. L., & Vereijken, B. (2016). Exergaming in older adults: movement characteristics while playing stepping games. *Frontiers in psychology, 7*, 964.

Skjæret, N., Nawaz, A., Morat, T., Schoene, D., Helbostad, J. L., & Vereijken, B. J. I. j. o. m. i. (2016). Exercise and rehabilitation delivered through exergames in older adults: An integrative review of technologies, safety and efficacy. *85*(1), 1-16.

Sturm, J. W., Donnan, G. A., Dewey, H. M., Macdonell, R. A., Gilligan, A. K., & Thrift, A. G. (2004). Determinants of handicap after stroke: the north east Melbourne stroke incidence study (NEMESIS). *Stroke, 35*(3), 715-720.

Subramanian, S. K., Lourenco, C. B., Chilingaryan, G., Sveistrup, H., & Levin, M. F. (2013). Arm motor recovery using a virtual reality intervention in chronic stroke: randomized control trial. *Neurorehabil Neural Repair, 27*(1), 13-23. doi:10.1177/1545968312449695

Teasell, R. W., Fernandez, M. M., McIntyre, A., & Mehta, S. (2014). Rethinking the continuum of stroke rehabilitation. *Arch Phys Med Rehabil, 95*(4), 595-596.

Vicon Motion Systems Ltd. (2016). Plug-in-Gait Reference Guide.

Weiss, P., Kizony, R., Feintuch, U., Katz, N., Cohen, L., Gage, F., . . . Duncan, P. (2006). Textbook of neural repair and rehabilitation. In: Cambridge University Press Cambridge, UK:.

Woodbury, M. L., Anderson, K., Finetto, C., Fortune, A., Dellenbach, B., Grattan, E., & Hutchison, S. (2016). Matching Task Difficulty to Patient Ability During Task Practice Improves Upper Extremity Motor Skill After Stroke: A Proof-of-Concept Study. *Arch Phys Med Rehabil, 97*(11), 1863-1871. doi:https://doi.org/10.1016/j.apmr.2016.03.022

Wüest, S., van de Langenberg, R., & de Bruin, E. D. (2014). Design considerations for a theory-driven exergame-based rehabilitation program to improve walking of persons with stroke. *European Review of Aging and Physical Activity, 11*(2), 119-129.

Öztuna, D., Elhan, A. H., & Tüccar, E. (2006). Investigation of four different normality tests in terms of type 1 error rate and power under different distributions. *Turkish Journal of Medical Sciences, 36*(3), 171-176.

Appendix 1

Intrinsic Motivational Inventory Questionnaire (IMI) oversatt til norsk

Spilloppgave: treffe fliser

ID nummer:______

For hver av de følgende påstandene, vennligst indiker hvor godt dette stemmer for deg, med bruk av følgende skala:

1	2	3	4	5	6	7
Helt uenig			Hverken eller			Helt enig

Fyll ut tabellen under:

	Spørsmål	**Score (1-7, der 1=helt uenig og 7=helt enig)**							**Vet ikke**
		1	**2**	**3**	**4**	**5**	**6**	**7**	
1	Jeg likte denne typen gangtrening godt - Forklaring: spille VR-spill mens du går på tredemølle								
2	Jeg syntes jeg var ganske god på å treffe flisene								
3	Jeg la mye innsats i å treffe flisene								
4	Jeg følte meg ikke nervøs i det hele tatt da jeg prøvde å treffe flisene								
5	Jeg tror at en slik type gangtrening kan være nyttig for meg								
6	Det var gøy å prøve og treffe flisene								
7	Jeg vil beskrive denne type gangtrening som spennende/interessant								
8	Etter å ha holdt på med denne spilloppgaven en stund, følte jeg meg ganske flink								
9	Jeg prøvde virkelig å gjøre det bra da jeg utførte denne spilloppgaven								
10	Jeg var anspent/bekymret da jeg utførte denne spilloppgaven								
11	Jeg er villig til å gjøre dette igjen fordi det har verdi for meg								
12	Jeg syntes det var ganske morsomt å prøve og treffe flisene								
13	Jeg er fornøyd med hvordan jeg gjorde det på spilloppgaven								
14	Det var viktig for meg å gjøre det bra på denne spilloppgaven								

15	Da jeg prøvde utførte spilloppgaven tenkte jeg på hvor morsomt jeg syntes det var								

Spilloppgave: unngå lister

ID nummer: ________

For hver av de følgende påstandene, vennligst indiker hvor godt dette stemmer for deg, med bruk av følgende skala:

1	2	3	4	5	6	7
Helt uenig			Hverken eller			Helt enig

Fyll ut tabellen under:

	Spørsmål	**Score (1-7, der 1=helt uenig og 7=helt enig)**							**Vet ikke**
		1	**2**	**3**	**4**	**5**	**6**	**7**	
1	Jeg likte denne typen gangtrening godt - Forklaring: spille VR-spill mens du går på tredemølle								
2	Jeg syntes jeg var ganske god på å unngå listene								
3	Jeg la mye innsats i å unngå listene								
4	Jeg følte meg ikke nervøs i det hele tatt da jeg prøvde å unngå listene								
5	Jeg tror at en slik type gangtrening kan være nyttig for meg								
6	Det var gøy å prøve og unngå listene								
7	Jeg vil beskrive denne typen gangtrening som spennende/interessant								
8	Etter å ha holdt på med denne spilloppgaven en stund, følte jeg meg ganske flink								
9	Jeg prøvde virkelig å gjøre det bra da jeg utførte denne spilloppgaven								
10	Jeg var anspent/bekymret da jeg utførte denne spilloppgaven								
11	Jeg er villig til å gjøre dette igjen fordi det har verdi for meg								
12	Jeg syntes det var ganske morsomt å prøve og unngå listene								
13	Jeg er fornøyd med hvordan jeg gjorde det på spilloppgaven								

14	Det var viktig for meg å gjøre det bra på denne spilloppgaven								
15	Da jeg utførte spilloppgaven tenkte jeg på hvor morsomt jeg syntes det var								

Spilloppgave: kognitiv

ID nummer: ______

For hver av de følgende påstandene, vennligst indiker hvor godt dette stemmer for deg, med bruk av følgende skala:

1	2	3	4	5	6	7
Helt uenig			**Noe enig**			**Helt enig**

Fyll inn tabellen under:

	Spørsmål	**Score (1-7, der 1=helt uenig og 7=helt enig)**							**Vet ikke**
		1	**2**	**3**	**4**	**5**	**6**	**7**	
1	Jeg likte denne typen gangtrening godt								
2	Jeg syntes jeg var ganske god på å finne objekter samtidig som jeg skulle treffe flisene								
3	Jeg la mye innsats i å finne objekter samtidig som jeg skulle treffe flisene								
4	Jeg følte meg ikke nervøs i det hele tatt da jeg prøvde å finne objektene samtidig som jeg skulle treffe flisene								
5	Jeg tror at en slik type gangtrening kan være nyttig for meg								
6	Det var gøy å prøve og finne objektene samtidig som jeg skulle treffe flisene								
7	Jeg vil beskrive denne typen gangtrening som spennende/interessant								
8	Etter å ha holdt på med denne spilloppgaven en stund, følte jeg meg ganske flink								
9	Jeg prøvde virkelig å gjøre det bra da jeg utførte denne spilloppgaven								
10	Jeg var anspent/bekymret da jeg utførte denne spilloppgaven								
11	Jeg er villig til å gjøre dette igjen fordi det har verdi for meg								
12	Jeg syntes det var ganske morsomt å finne objekter samtidig som jeg skulle treffe flisene								

13	Jeg er fornøyd med hvordan jeg gjorde det på spilloppgaven								
14	Det var viktig for meg å gjøre det bra på denne spilloppgaven								
15	Da jeg utførte spilloppgaven tenkte jeg på hvor morsomt jeg syntes det var								

ID nummer: ______

Tilleggsspørsmål

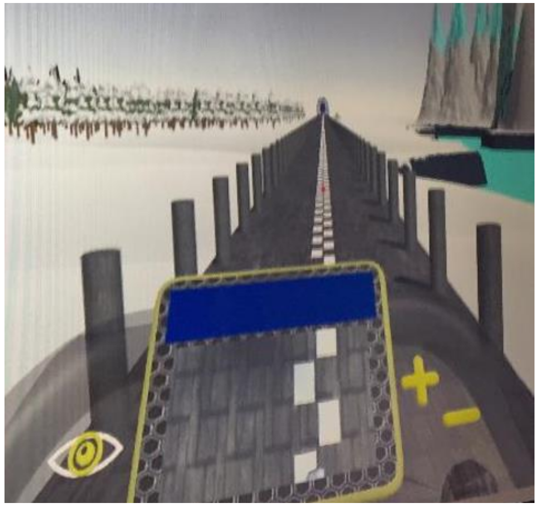
	Spørsmål	Svar	Vet ikke
1	Hvilke av de tre spilloppgavene likte du best? Treffe, unngå, kognitiv?		
2	Hvilke av de tre spilloppgavene syntes du var mest motiverende? Treffe, unngå, kognitiv?		
3	Var noen av spilloppgavene for vanskelig?		
4	Hvilke elementer i spillet hadde størst påvirkning på din motivasjon? F.eks. feedback fra spillet, den virtuelle verdenen, spill elementene.		

For hver av de følgende påstandene, vennligst indiker hvor godt dette stemmer for deg, ved å peke på følgende skala:

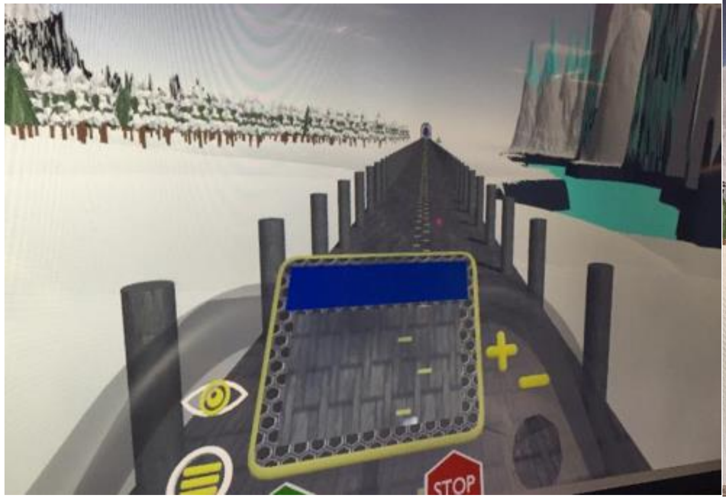
1	2	3	4	5	6	7
Helt uenig 			**Hverken eller** 			**Helt enig** 

Tilleggsspørsmål

Treffe



Unngå



Kognitiv

Appendix 2

Original IMI:

Interest/enjoyment

1. I enjoyed doing this activity very much.
2. This activity was fun to do.
3. I thought this was a boring activity (R).
4. This activity did not hold my attention at all (R).
5. I would describe this activity as very interesting.
7. I thought this activity was quite enjoyable.
8. While I was doing this activity, I was thinking about how much I enjoyed it.

Perceived competence

1. I think I am pretty good at this activity.
2. I think I did pretty well at this activity, compared to other patients.
3. After working at this activity for a while, I felt pretty competent.
4. I am satisfied with my performance at this task.
5. I was pretty skilled at this activity.
6. This was an activity that I couldn't do very well (R).

Effort/Importance

1. I put a lot of effort into this.
2. I didn’t try very hard to do well at this activity (R)
4. I tried very hard on this activity.
5. It was important to me to do well at this task.
5. I didn’t put much energy into this. (R)

Pressure/Tension

1. I did not feel nervous at all while doing this. (R)
2. I felt very tense while doing this activity.
3. I was very relaxed in doing these. (R)
4. I was anxious while working on this task.
5. I felt pressured while doing these tasks

Value/Usefulness

1. I believe this activity could be of some value to me.
2. I think that doing this activity is useful for ______________________.
3. I think this is important to do because it can ______________________.
4. I would be willing to do this again because it has some value to me.
5. I think doing this activity could help me to ______________________.
6. I believe doing this activity could be beneficial to me.
7. I think this is an important activity.

Appendix 3

Infoskriv og samtykkeskjema

NTNU
Kunnskap for en bedre verden

FORESPØRSEL OM DELTAKELSE I FORSKNINGSPROSJEKTET

GJENNOMFØRBARHET AV VR-TRENINGSSPILL HOS PERSONER MED HJERNESLAG

Dette er et spørsmål til deg om å delta i et forskningsprosjekt i samarbeid med Institutt for nevromedisin og bevegelsesvitenskap og Institutt for datateknologi og informatikk.

Hensikten med studien er å undersøke gjennomførbarhet av et spesialdesignet VR-spill på en tredemølle hos slagpasienter. Du spørres om å delta i studien fordi du har vært/er på opptrening på St. Olavs Hospital, Klinikk for fysikalsk medisin og rehabilitering, avdeling for ervervet hjerneskade.

HVA INNEBÆRER PROSJEKTET?

Studien er en observasjonsstudie der du blir bedt om å spille et treningsspill med ulike oppgaver og elementer som kan påvirke ditt gangmønster. Når du går på tredemølla har du på deg VR-briller. VR-briller, eller virtuell reality-briller, er et apparat som dekker hele synsfeltet ditt. Disse brillene gir tredimensjonalitet og dybdesyn, og handler om å skape overbevisende illusjoner. Nærmere bestemt illusjonen av å være tilstede – virkelig, fysisk tilstede – i et dataprogrammert kunstig miljø. Med disse brillene kan du se deg omkring i alle retninger uten å bryte illusjonen. Bevegelsene du gjør når du går på mølla vil være koblet til den virtuelle virkeligheten og gi deg tilbakemelding på hvordan du går. Hastigheten man går fremover i spillet med samstemmer med den virkelige hastigheten man går med på tredemøllen, som du selv kontrollerer. Du vil bli sikret med opphengssele i taket når du går på tredemølla. Dette medfører ikke noe form for ubehag og er kun der for å gi ekstra sikkerhet. Det vil alltid være minst to personer fra prosjektgruppen til stede under testingen, der en av disse kun har ansvar for din sikkerhet.

Spillet består av tre ulike oppgaver. Direkte etter hver oppgave vil du bli bedt om å svare på et spørreskjema sittende. Dette er for å kartlegge din motivasjon for å spille spillet. Spørsmålene i spørreskjemaet kan leses opp for deg dersom du har behov for det, og du svarer ved hjelp av å peke på en skala fra 1-7 som indikerer om du er enig eller uenig.

Datainnsamlingen vil foregå på Visualiseringslaboratoriet ved IDI Kalvskinnet på NTNU. Før spillingen starter vil en fysioterapeut gjøre noen enkle fysiske tester for å vurdere om det er noen forhold som påvirker din evne til å spille spillet. Det vil også bli utført en gangtest på gulv. Du vil få mulighet til å prøve tredemøllen uten briller, og deretter med briller uten spillelementer. Testingen vil ta mellom 60-90 minutt fra start til slutt, og alt dette gjøres samme dag. En ansatt ved arbeidsstedet har vurdert at du klarer å gå selvstendig på tredemølle, og at du har en funksjon som tilsier at du kan delta i studien. Totalt vil det være opptil 10 deltakere med slag (>3 måneder etter slaget).

Dersom du velger å bli med på studien vil du bli bedt om å ha på/ta med deg lette klær. Dette av hensyn til plassering av markører knyttet til 3D bevegelsesopptak. I tillegg vil du også bli bedt om å møte i eller ta med gode sko, slik at du kan gå stødig og uten at det påvirker måten du beveger deg på.

I prosjektet vil vi innhente og registrere opplysninger om deg. Vi vil innhente bakgrunnsinformasjon og undersøke om det er forhold som påvirker din evne til å spillet spille mens du går på tredemølle. 3D-kameraer, akselerometer og spillet vil registrere informasjon om ditt gangmønster, og vi vil i tillegg ha digital video for kvalitetssikring av data. Ved hjelp av et spørreskjema vil vi innhente informasjon rundt din motivasjon til å spille spillet.

MULIGE FORDELER OG ULEMPER

Det forventes ingen ulemper eller sikkerhetsrisiko ved gjennomføring av utprøving av 3Dmølla. Risikoen for uønskede hendelser (fall og/eller skader) er veldig lav og du vil bli sikret med opphengs sele. Noen kan oppleve lett ubehag eller kvalme ved bruk av VR-briller. Det minner om sjøsyke og kan oppstå når det er et ikke er samsvar mellom det du ser og det som registreres av kroppen din. Det er ikke farlig og vil gå over når man tar av VR-brillene. Dersom dette skulle oppstå avbrytes utprøvingen umiddelbart.

FRIVILLIG DELTAKELSE OG MULIGHET FOR Å TREKKE SITT SAMTYKKE

Det er frivillig å delta i prosjektet. Dersom du ønsker å delta, undertegner du samtykkeerklæringen på siste side. Du kan når som helst og uten å oppgi noen grunn trekke ditt samtykke. Dette vil ikke få konsekvenser for din videre behandling. Dersom du trekker deg fra prosjektet, kan du kreve å få slettet innsamlede prøver og opplysninger, med mindre opplysningene allerede er inngått i analyser eller brukt i vitenskapelige publikasjoner. Dersom du senere ønsker å trekke deg eller har spørsmål til prosjektet, kan du kontakte prosjektleder professor Beatrix Vereijken, mobilnr: 984 25 974, e-post: beatrix.vereijken@ntnu.no

HVA SKJER MED OPPLYSNINGENE OM DEG?

Opplysningene som registreres om deg skal kun brukes slik som beskrevet i hensikten med prosjektet. Informasjonen skal brukes til å skrive to masteroppgaver, og vil bli forsøkt publisert som en del av en doktorgradsavhandling. Du har rett til innsyn i hvilke opplysninger som er registrert om deg og rett til å få korrigert eventuelle feil i de opplysningene som er registrert. Du har også rett til å få innsyn i sikkerhetstiltakene ved behandling av opplysningene.

Alle opplysningene vil bli behandlet uten navn og fødselsnummer eller andre direkte gjenkjennende opplysninger. En kode knytter deg til dine opplysninger gjennom en navneliste.

Det er kun prosjektleder professor Beatrix Vereijken som har tilgang til denne navnelisten. Prosjektleder har ansvar for den daglige driften av forskningsprosjektet og at opplysninger om deg blir behandlet på en sikker måte. Personidentifiserende informasjon om deg vil bli anonymisert ved prosjektets slutt, juni 2020, og avidentifiserte data oppbevares for eventuelt fremtidig kvalitetssikring i fem år etter prosjektets slutt (til juni 2025).

FORSIKRING

Hvis det skulle oppstå skader underveis i testingen som kan knyttes til testsituasjonen, så må deltaker melde dette til prosjektleder. Deltakere er dekket av Norsk Pasientskadeerstatning. NTNU tar ansvar for skader som følge av testsituasjonen, og dekker utgifter til medisinsk behandling hvis dette skulle oppstå.

ØKONOMI

Reisekostnader for deltakere dekkes av prosjektet.

GODKJENNING

Regional komité for medisinsk og helsefaglig forskningsetikk har vurdert prosjektet, og har gitt forhåndsgodkjenning [saksnr. 50926 hos REK, 18/11/2019].

Etter ny personopplysningslov har behandlingsansvarlig NTNU og prosjektleder professor Beatrix Vereijken et selvstendig ansvar for å sikre at behandlingen av dine opplysninger har et lovlig grunnlag. Dette prosjektet har rettslig grunnlag i EUs personvernforordning artikkel 6 nr. 1a og artikkel 9 nr. 2a og ditt samtykke.

Du har rett til å klage på behandlingen av dine opplysninger til Datatilsynet.

KONTAKTOPPLYSNINGER

Dersom du har spørsmål til prosjektet kan du ta kontakt med prosjektmedarbeider Johanna Flå, mobilnr: 90 12 97 98, e-post: johannfl@stud.ntnu.no

Personvernombud ved institusjonen er thomas.helgesen@ntnu.no

JEG SAMTYKKER TIL Å DELTA I PROSJEKTET OG TIL AT MINE PERSONOPPLYSNINGER BRUKES SLIK DET ER BESKREVET

Sted og dato   Deltakers signatur

Deltakers navn med trykte bokstaver

NTNU

Norwegian University of
Science and Technology