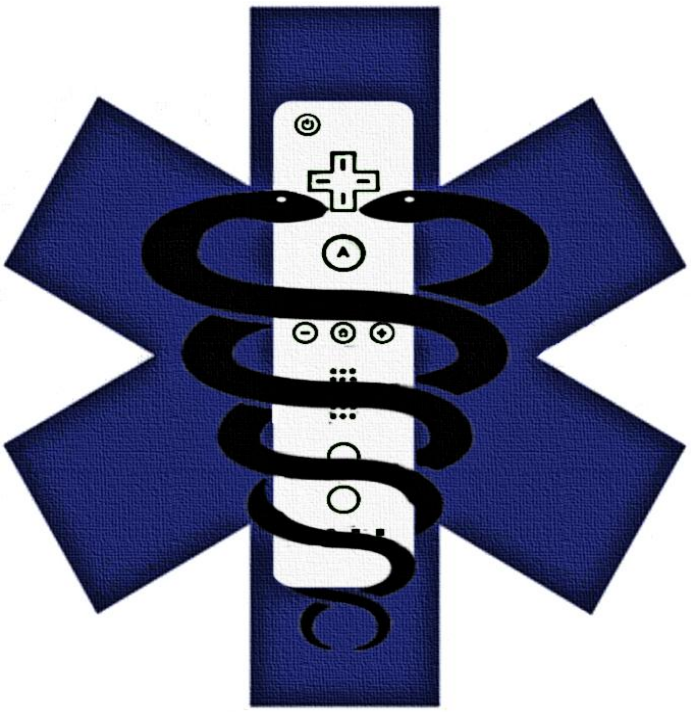
-Bachelor thesis-

"Wii-habilitation": The use of motion-based game consoles in stroke rehabilitation; a systematic review



January 2014

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Abstract

Background: Current motor rehabilitation strategies for people who suffered a stroke focus on occupational therapy and physiotherapy and rely on repetitive, intensive and task-oriented training of the body parts that are affected by functional impairments. Though these training methods are generally effective, rehabilitation therapy is often perceived as monotonous and mundane, which could result in an incomplete recovery as patients lack in motivation to do the training exercises as recommended. Motion-based gaming consoles as the Nintendo Wii offer several ways for deployment that can help to facilitate the recovery of motor functionality and increase patient motivation. A great number of health practitioners affirm that the Wii is a feasible tool for stroke rehabilitation purposes. Still, relevant research that focuses on an assessment of the feasibility of the system is limited and there is a need for more comprehensive work in this field.

Objective: This systematic review aims at summarizing the scientific work that is done in the field of integrating the Nintendo Wii into rehabilitation interventions for stroke patients.

Methods: The review is based on a systematic literature search that was focused on interventions that make use of games and game elements in health contexts. The initial search yielded 4556 publications that were subsequently screened with regard to their relevance for this review, by using several established eligibility criteria. The use of these criteria ensured that the studies, that were featured in this review included a discrete intervention that was aimed at stroke rehabilitation and incorporated the Nintendo Wii. The data that were extracted from these studies were categorized into 5 different fields, namely study characteristics, intervention characteristics, evaluation of outcome measures, major advantages and limitations.

Results: The final outcome of the screening phases yielded a number of 9 publications that met all of the established criteria for the inclusion in this systematic review. The major results that were derived from these interventions showed that Wii-based stroke therapy leads to significant improvements in motor functionality and increases patient motivation and engagement. Major advantages of the Wii system include the absence of adverse effects and the possibility that the Wii can be used for patients in the chronic phase post-stroke. Major limitations were identified as the Wii-gaming exercises required constant supervision and additional input from therapists and the integrated game feedback was not sensitive to measure a patient´s performance and progress in a compatible way.

Conclusions: The findings of this research suggest that the Nintendo Wii is a feasible tool for stroke rehabilitation purposes that can keep up with traditional therapy approaches with regard to the functional outcomes and succeeds in enhancing active participation in the therapy sessions. The use of the system holds limitations in the field of home deployment as it requires constant attendance by healthcare professionals. Still, the results of this study suggest that the system is feasible for a wide-scaled integration into stroke therapy.

Samenvatting

Achtergrond: Tegenwoordig gebruikte motor rehabilitatie strategieën voor mensen na een beroerte richten zich op ergotherapie en fysiotherapie en werken met repetitieve, intensieve en taak georiënteerde oefeningen van de lichaamsdelen met functionele beperkingen. Hoewel deze oefeningen over het algemeen effectief zijn worden zij vaak als monotoon en saai ervaren. Dit leidt mogelijk tot een incomplete herstel, omdat patiënten vaak niet gemotiveerd zijn om de aanbevolen oefeningen uit te voeren. Motion-based gaming consoles zoals de Nintendo Wii bieden verschillende gebruiksmogelijkheden welke helpen het herstel van motorische functies te vergemakkelijken en de motivatie van patiënten te verhogen. Vele verpleegkundigen bevestigen dat de Nintendo Wii een bruikbaar hulpmiddel is voor de rehabilitatie van een beroerte. Relevante onderzoeken die zich op de bruikbaarheid van het systeem richten zijn echter gelimiteerd en meer uitgebreid wetenschappelijk werk is nodig.

Doel: Deze systematische review is daarop gericht wetenschappelijk werk samen te vatten dat in het veld van de integratie van de Nintendo Wii in interventies voor beroerte rehabilitatie gedaan is.

Methodes: De studie is gebaseerd op een systematische literatuur zoektocht die gefocusseerd was op interventies die games en game elementen in de gezondheidszorg gebruiken. De initiële zoektocht leverde 4556 publicaties welke vervolgens gescreend werden op hun relevantie voor dit review, met behulp van vastgelegde selectiecriteria. Door het gebruik van deze selectiecriteria werd verzekerd dat de studies die voor dit onderzoek geselecteerd werden alle een aparte interventie bevatten die op beroerte rehabilitatie gericht is en daarbij gebruik maakt van de Nintendo Wii. De data uit de gekozen studies werden in vijf verschillende categorieën ingedeeld, namelijk studie eigenschappen, interventie eigenschappen, evaluatie van de resultaten, belangrijke voordelen en limitaties.

Resultaten: De finale uitkomst van de screening fasen leverde 9 publicaties welke aan alle opgestelde selectiecriteria van de systematische zoektocht voldeden. De belangrijkste resultaten van deze interventies laten zien dat beroerte therapie, gebaseerd op de Nintendo Wii tot een significante verbetering van de motor functies leidt en bovendien de motivatie en participatie van patiënten verhoogd. De belangrijkste voordelen van het Wii systeem zijn het ontbreken van nadelige gevolgen en complicaties en de mogelijkheid om het ook voor patiënten in te zetten die zich in de chronische fase van een beroerte bevinden. Belangrijke beperkingen van de Nintendo Wii zijn dat de Wii-gaming oefeningen een voortdurend toezicht en extra inbreng van therapeuten noodzakelijk maken en de geïntegreerde game feedback niet gevoelig is om de prestaties en de vooruitgang van patiënten op een passende wijze te meten.

Conclusies: De gevonden resultaten tonen aan dat de Nintendo Wii een bruikbaar hulpmiddel voor beroerte rehabilitatie is en de effectiviteit met betrekking tot de functionele resultaten vergelijkbaar is met de effectiviteit van traditionele therapieën. Verder wordt de actieve participatie van patiënten tijdens de therapie verbeterd. De Nintendo Wii heeft limitaties in de inzet voor het thuis gebruik omdat het een constante begeleiding van hulpverleners vereist. Desondanks suggereren de resultaten van dit studie dat een grootschalige inzet van het systeem in beroerte rehabilitatie voordelig is.

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Introduction

Stroke is one of the world´s most devastating diseases, counting more than 15 million incidents worldwide each year of which one third results in immediate death (Santayayon, Pipitpukdee, & Phantachat, 2012). It is not only ranked as third under the causes of death in industrialized countries, but it is also the leading cause of acquired adult disabilities. About 85% of people who survived a stroke experience an immediate hemiparesis; up to 75% continue to experience persistent motor impairments. These impairments typically affect the motor control functions of the face and the upper and lower limbs. In most cases it is one side of the body that is affected, resulting in limitations or a total loss in movement control of the muscles in the particular areas (Langhorne, Coupar & Pollock, 2009; Saposnik et al., 2010). Frequently occurring consequences of stroke are loss of balance, weakness and paralysis of the affected body parts and persistent feelings of pain, but also cognitive impairments as aphasia or deficiencies in attention and concentration (Burke, McNeill, Charles, Morrow, Crosbie & McDonough, 2009). Such impairments originate from a stroke´s medical nature. Stroke, also referred to as cerebrovascular accident, is a medical condition that is caused by a temporary loss of blood flow to a certain brain area. This loss of blood flow results from obstructions in an artery, as caused by blood clots (ischemia) or from ruptures in an artery as a consequence of a head injury (hemorrhage) (Kalat, 2003). Impairments in motor functions occur as lesions and ischaemic injuries affect the brain areas of the motor cortex, the pre-motor cortex or other brain areas that are associated with motor function and movement control (Langhorne et al., 2009). Restrictions in the motor functionality are generally associated with a diminished quality of life as people who suffered a stroke are often incapable of continuing work and have difficulties in performing their routine everyday activities independently (Alankus, Proffitt, Kelleher, & Engsberg, 2011). For this reason, much of the focus of stroke rehabilitation is set on the recovery of the lost motor functions.

Current motor rehabilitation strategies for people post-stroke focus on occupational therapy and physiotherapy and rely on repetitive, intensive and task-oriented training of the body parts that are affected by paresis. Through the execution of repetitive exercises the brain is provided with an effectual amount of stimuli that leads to a remodeling of the impaired brain areas and promotes a partial recovery of the motor functionality (Alankus et al., 2011). It has been found that these training methods are generally effective and beneficial for the recovery of the impaired motor functions (Langhorne et al. 2009). Their effectiveness however crucially depends on an immediate begin of therapy and the conduction of

continuous, intensive practice. This is essential since maximum improvements in the rehabilitation of motor functions are generally achieved within the first five months after stroke (Celinder & Peoples, 2012; Saposnik et al., 2010). First phases of therapy usually take place during hospitalization, but once patients are sent home, they are required to travel to specialized facilities in order to continue their therapy under the supervision of professionals. Stroke patients that take part in such forms of outpatient therapy are confronted with a number of problems. First of all, the necessity for transportation can be a problem for patients and their families, as it demands a great amount of time and it creates additional transportation costs to the costs of therapy itself. Transportation can also be very arduous for patients, especially when their condition has not fully stabilized. Furthermore, treatments in the field of stroke rehabilitation are in most cases administered by occupational therapists and physiotherapists on a one-to-one basis; this demands high expenditures in staff which again leads to increases in the costs of healthcare (Burke et al., 2009; Saposnik et al., 2010).

In order to overcome these problems, many health practitioners make use of so called home-based rehabilitation designs. Such therapy approaches allow patients to continue therapy in their home environment by performing prescribed home-exercises as a part of their outpatient therapy; frequent visits to stroke facilities are partly replaced by home therapy sessions, as occupational and physiotherapists attend to patients in home-visits. Problems that come with transportation can be avoided this way; further it has been found that the familiar surrounding and the presence of the family have positive effects on the therapy outcomes (Alankus et al. 2011; Burke et al., 2009). A number of studies have examined the general effectiveness of home based therapy approaches in comparison with conventional outpatient therapy. The findings of these studies suggest that home therapy is a feasible alternative to the more traditional approaches as it yields similar effectual outcomes with similar to lower costs (Anderson, Mhurchu, Brown & Carter, 2002; Shepperd at al., 2009).

While home-based rehabilitation approaches seem to be an effective way to overcome parts of the drawbacks of traditional rehabilitation therapy, they still harbor several problems. The therapy outcomes largely depend on a patient´s motivation. As said, rehabilitation therapy for motor recovery focuses on continual repetitions of intense, task-oriented exercises, which is why it is often perceived as monotonous and mundane. It is indicated that only 31% of patients in home-based therapy perform their prescribed exercises as recommended, which often results in an incomplete recovery. Furthermore, stroke patients do frequently suffer from depression, considering their condition and the often serious impairments. Such additional complaints can also affect their ability to concentrate on therapy

exercises and, subsequently, have a negative impact on the general therapy outcomes (Alankus et al. 2011; Burke et al., 2009). To ensure patient motivation and active participation it is necessary that stroke patients receive adequate, individual feedback on their progress and realistic goals that they can work towards. This however demands home-visits of therapists, which again creates additional costs and is often not possible due to shortages of manpower. A further problem that arises is that home-based therapy generally requires the acquisition of expensive equipment. Therefore, it is difficult for families with low income to make use of such therapy designs (Bateni, 2012; Burke et al., 2009).

Commercially available gaming consoles offer several ways for home deployment that can avoid many of these obstacles. Contemporary digital gaming consoles reach a broad demographic group and the comparatively low costs, and the ease of purchase make these gaming systems accessible and affordable for a broad field of patients. The most representative consoles as the Sony Playstation 3™, the Microsoft X-box 360™ and the Nintendo Wii™ are often referred to as "Virtual Reality" based consoles, because these systems offer the user the possibility to interact with computer generated 3-dimensional environments (Saposnik et al., 2010). The Nintendo Wii, released in November 2006, holds a special position under the newer generation of gaming consoles, because its main focus is set on motion-based interactions. The system works with movement detection by using a handheld pointing device, which is called the "Wii-mote". This device comes with integrated sensors that can track and respond to the direction, acceleration and the speed of a user´s wrist, arm and hand movements. The system also offers multiple purchasable expansions like the Wii Motion Plus, which allows more accurate sensor tracking, or the Wii Balance Board, a platform device that measures the distribution of weight bearing. Users can playfully interact with the system by movement control; the movements are then converted to virtual avatars and make it possible for the user to monitor his or her own activities (Santayayon et al., 2012; Saposnik et al., 2010).

Due to its great popularity the Nintendo Wii has received growing attention of healthcare professionals all over the world. In the last few years there has been a substantial increase in the integration of the Nintendo Wii into health contexts. In fact, the term "Wii-habilitation", also referred to as "Wii-hab", has established itself under health practitioners that work in the field of occupational therapy (Anderson, Annett & Bischof, 2010). The Nintendo Wii holds great capabilities in the field of motor rehabilitation for patients post-stroke, as it can be used as a training tool for several of the exercises that are part of conventional occupational therapy: It can be applied to work on the dexterity of the hand

functions, the control and range of the gross and fine motor functions, balance and the general fitness of a patient. A great number of health practitioners and researchers affirm its validity and reliability in health practice (Bateni, 2012; Santayayon et al., 2012). Initial therapeutic implementation approaches state that the entertaining sphere of Wii-gaming can encourage patients to continue therapy for longer periods of time, because they do not perceive it as irritating or a hindrance. In fact, Wii-habilitation treatments have been found to bring higher levels of patient satisfaction compared to usual therapy (Anderson et al., 2010; Burke, 2009). It is also reported that the intensive use of the Nintendo Wii results in decreased depressive symptoms and brings improvements in the cognitive performance of patients post-stroke (Bateni, 2012).

Even though the Nintendo Wii seems to be a promising tool for rehabilitation, its adaptation into therapy also has its limitations. The console itself was created for entertainment purposes and the games are designed to be played by people without physical constraints. Implementing the Nintendo Wii as a stand-alone application for motor rehabilitation leads to the emergence of several problems. Because the difficulty of the standard Wii games is calibrated for healthy players, many of these games are too challenging or even unplayable for people with motor impairments. The system also does not provide a rehabilitation-specific feedback which makes it difficult for patients and health practitioners to track progresses over longer periods of time (Anderson et al., 2010). Because the demanded interactions and motions are not designed for therapeutic purposes, some studies even suggest that the use of the Nintendo Wii can be potentially harmful for the user. Among the reported injuries that result through intensive use of the Wii are discomforts and injuries in the shoulder and the knee, fractures in the spinal cord and again some forms of ischaemic stroke (Bateni, 2012).

As it can be seen, opinions on the feasibility of the Nintendo Wii for stroke rehabilitation purposes are still divided. Though the general findings of existing research indicate that it is a feasible tool for rehabilitation therapy, published studies are limited and relevant research into the clinical application of the Nintendo Wii is lacking (Bateni, 2012; Kim, Kang, Park & Jung, 2012). More comprehensive work is needed to draw relevant conclusions about the advantages and disadvantages of integrating the Nintendo Wii into stroke rehabilitation, before it can be applied on a wider scale. A directed search yielded one systematic review that was aimed at assessing the feasibility and the effectiveness of the Nintendo Wii as a tool for stroke therapy. The findings of the study indicated that the use of the Nintendo Wii is beneficial with regard to therapeutic outcomes, as all of the included

studies showed predominantly positive results (Santayayon et al., 2012). The informative value of this review is, however, questionable as descriptions of the included interventions lack in detail and the focus of the results is set on naming the findings in the functional outcomes without giving a proper interpretation.

In order to contribute to the scientific field of Wii-based stroke rehabilitation and to add to the comprehensive articles, the following paper attempts on summarizing the findings of the existing literature. The objective of the present review is to give an accurate insight into the use of the Nintendo Wii in interventions that are directed at the rehabilitation of stroke. It will give a detailed description of how these interventions are structured and implemented; it will further try to give insight into the measurements of effectiveness when such measures are provided and it will determine and name the most important advantages and disadvantages of such interventions. In this connection it will try to answer the four following research questions:

1.) *What are the characteristics of Wii-based interventions that are directed at stroke rehabilitation?*

2.) *What can be said about the effectiveness of the Nintendo Wii in the context of stroke rehabilitation?*

3.) *What are the major advantages that come with the integration of the Nintendo Wii into stroke rehabilitation?*

4.) *Which limitations arise in the study- and intervention design of Wii-based stroke therapy approaches?*

By answering these questions, the review attempts to bring clarity into the discussion of whether the Nintendo Wii is feasible for a wide scaled clinical application or not.

Methods

Search strategy

This review is based on a comprehensive literature search, which took place under the broader framework on "the use of games and gamification in health care". Set as a part of the University of Twente´s bachelor degree program, the goal of this framework was to gain insight into how games and game-elements can be integrated into health related intervention- and therapy programs. With our research team we created a systematic search strategy that aimed at generating a literature library that covers an important part of the present state of research in the field of gaming interventions in health contexts. Four scientific databases were selected to serve as a source for the initial search: 1.) PsycINFO, 2.) ScienceDirect, 3.) SciVerse Scopus and 4.) Web of Knowledge. The basis of the used search strategy was formed by so called search constructs, which were created prior to the conduction of the initial search. The search constructs were designed in dependence of the advanced search functions of the four respective databases; each of these constructs was directed at one specific sector of how games can be integrated into health purposes and included a number of related keyterms. Four constructs were created, each consisting of several related keyterms:

1.) The "technical construct" consists of terms from the technical/multimedia sector that ensure that the emerging interventions are conducted by means of a digital medium;

2.) the "game construct" holds a number of terms that ensure that the emerging interventions include some kind of game or are conducted in a playful manner;

3.) the "health construct" compiles terms from the medical sector; it was established to guarantee that the emerging interventions are directed at health promotion;

4.) the "procedure construct" consists of the terms "Therapy" and "Intervention"; the construct was added to make sure that the emerging literature does include some kind of intervention or therapy approach.

The four established search constructs and the respective keyterms of each construct are illustrated in *Figure 1* (see next page).

Figure1. Search constructs with the respective keyterms.

After establishing the four search constructs, the initial search was conducted on October 1st, 2013. It was done by means of a combined search; that is to say that the search only yielded articles that included at least one of the terms from each of the respective search constructs. By doing so, we made sure that the search covers a broad number of studies that hold relevant information to the topic. The initial search led to the identification of 4556 publications that met our demands in terms of the search constructs. This number was reduced to 3204 articles through the removal of duplicate articles. The remaining articles were then screened with regard to their content and their relevance for our research. This was done by the use of several eligibility criteria, which were determined in advance. The criteria for inclusion were as follows:

1.) The articles had to include some form of intervention, application or therapy approach;

2.) the included intervention was aimed at patients or people with health issues;

3.) the intervention was aimed at the promotion of such health issues;

4.) the intervention had to work with some form of game or at least with game elements; and

5.) the intervention was made available by digital means.

Articles were excluded if they:

1.) included no information about the design of the intervention/ application/therapy or,

2.) if they were reviews, which means they included no discrete research.

The articles were screened for eligibility by two members of our research team. Both members did a separated screening of the titles and the abstracts, which means that both members handled the in- and exclusion criteria independently. The findings were compared and discussed between and after the two screening phases. When the two members did not agree in terms of the in- or exclusion of an article, it led to the unconditional inclusion of the respective article. The screening phases provided a final number of 362 articles that fulfilled all our requirements concerning their content, buildup and their importance to our topic.

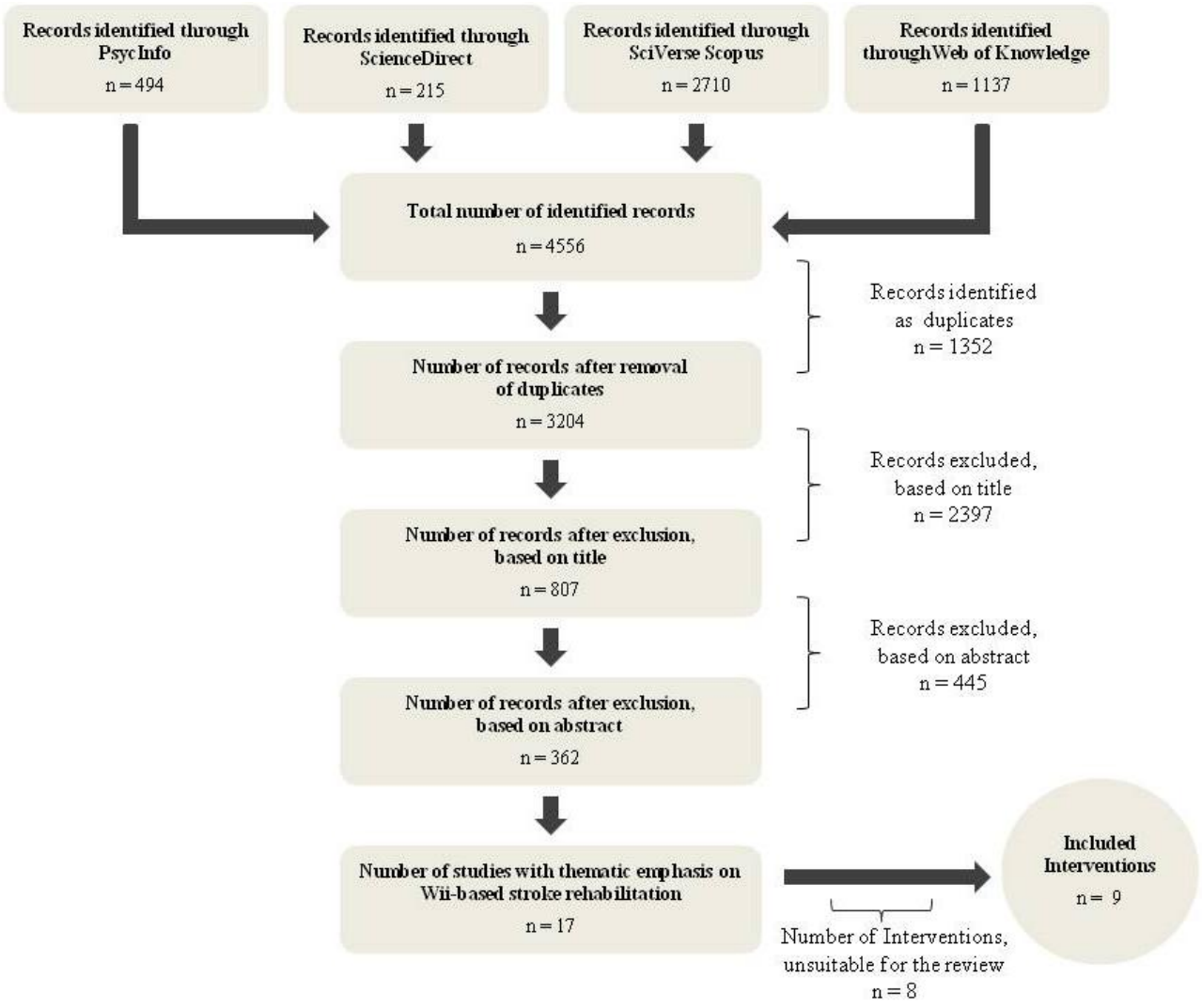
Study selection

The 362 publications that were derived from the screening phases formed the literature library that was the initial goal of the framework of "*the use of games and gamification in health care"* as all of them included some form of intervention that was directed at the promotion of health and worked with games or game elements. The continuative task for the students that worked on this framework was to select articles that are directed at the individual topics, which the students had chosen in advance, and to write a scientific review, based on the findings of these articles. As it was decided that the present review should lay a special focus on interventions that are directed at motor rehabilitation for stroke patients and thereby integrate the Nintendo Wii gaming system, the 362 articles were again scanned with regard to their thematic emphasis. First, all interventions were filtered out that did not incorporate the Nintendo Wii; the remaining interventions were then divided into the specific sections of health care at which they were directed. This procedure led to the identification of 17 interventions that worked with the Nintendo Wii and addressed the motor recovery of patients post-stroke.

The following step was to screen the 17 selected articles for eligibility, based on the full-text articles. This was done by means of the eligibility criteria that were also handled during the title and abstract screening phases. Two studies were excluded because of the unavailability of the full-text articles; one article was excluded as it was only available in Chinese language. A further problem was met, regarding 5 of the 14 articles, as they only presented qualitative data on an intervention design, without including an assessment of the

intervention effects. Because making assumptions about the general effectiveness of Wii-based stroke rehabilitation interventions was established as one of the goals of this present paper, it was decided to further exclude these 5 articles. The last screening phase led to the final outcome of 9 publications, which formed the base for the further course of the data extraction. *Figure 2* illustrates the several phases of screening and study selection, including the respective number of articles that were in- and excluded in each phase.

Figure 2. Flow diagram of study selection.



Data extraction and analysis

As determined in the beginning, the focus of the present review was set on identifying the most important characteristics of Wii-based interventions that are directed at stroke patients and on making assumptions about the general effectiveness of these interventions. It further aimed at naming important advantages and limitations that can be derived from such interventions. In order to systematically assess all the information that was relevant to these research purposes it was decided to establish categories in which the emerging data could be grouped. The five established categories for data extraction will be described in the following.

Study characteristics

The first category of study characteristics contains information about the general study purpose and the methodological study design of the included interventions. It also includes information about the different demographic features and the forms of functional impairments that were met in the used participant groups. Further information that are covered in this category are information about the used measuring instruments, that is to say the way in which the data were obtained (qualitative, quantitative), what data were obtained and which tools were used for the assessment of this data.

Intervention characteristics

The category of intervention characteristics includes information about the intervention set-up and the characteristics of the games that were used in the respective interventions. With regard to the intervention set-up, this category comprises data about the duration in which the interventions took place, it lists the number and the time of intervention sessions and gives information about how the intervention process was conducted and administered. The assessment of game characteristics is directed on the different kinds of games that were used in each of the interventions; it further includes information about the reasons for why these games were chosen and which special adjustments had to be made before the games could be played.

Evaluation of outcome measures

The evaluation of outcome measures forms the third category for data extraction; it comprises data about the different outcomes of the nine included interventions. The category is split up into two subsections of which the first is directed at the evaluation of outcome measures, according to the researchers of the respective interventions. It addresses both qualitative and quantitative outcome measures and further gives information on whether the outcomes were significant or not. Because the 9 included interventions were expected to differ in the used measuring instruments and the form of the functional outcomes, it was decided to do a second evaluation of the outcome measures that eases comparisons between the outcomes of the different studies. This second evaluation was done using general criteria for defining the effectiveness of an intervention that were derived from the work of Morrison, Yardley, Powell and Michie (2012). The evaluations that were done, based on these criteria, are listed under the general outcome measures and form the second fraction of this category. The criteria that were used in this second evaluation are listed in *Table 1*.

Table 1. Criteria for defining intervention effectiveness, according to Morrison et al. (2012)

Intervention code	Criteria
More effective	- The intervention led to improvement on the *majority* of outcomes measures. - The intervention was at least *as effective* as comparison groups. - The intervention was *more effective* than waiting list or no intervention control groups
Less effective	- The intervention led to improvement on a *minority* of outcomes measures. - The intervention was *not necessarily as effective* as comparison groups. - The intervention was *more effective* than waiting list or no intervention control groups.
Ineffective	- The intervention *did not lead to improvement* in any of the outcome measures. - The intervention was *no more effective* than waiting list or no intervention control groups.

Major Advantages

The fourth category focuses on the major advantages of integrating the Nintendo Wii for stroke rehabilitation purposes. Information about the advantages was derived from the general outcomes of the nine interventions and from accentuations that were made by the authors of the respective studies.

Limitations

The last category for data extraction is the category of limitations. The category is divided into two subsections: The first section lists important limitations that were found in the study design and the general structure of the intervention; the second section, which is of greater importance to our topic lists limitations that were met during the conduction of the respective interventions. Data that are covered in this subsection are information on problems that were encountered during game-play or adjustments that were needed to be taken during the intervention periods.

By using the five categories for data extraction it was ensured that the results yield relevant information to the topic and no data was missing that was needed to answer the four research questions that were constituted in the beginning of this research.

Results

The final outcome of the systematic literature search yielded a number of 9 publications that met all of the established criteria for the inclusion in this systematic review; all 9 publications include a discrete intervention that is directed at the rehabilitation of stroke and thereby utilizes the Nintendo Wii. They are listed in *Table 2*; the table displays the authors, the titles and also the year and the country of publication of each of the respective articles. Furthermore, each of the 9 articles was labeled with an intervention code, which is also displayed in the last column of *Table 2*. These codes were added, in order to ease references to the 9 included interventions and facilitate comparisons.

Table. 2: List of included interventions

Authors	Title of publications	Year and country of publication	Intervention code
Alankus, G., Proffitt, R., Kelleher, C. & Engsberg, J.	*Stroke therapy through motion-Based games: A case study*	2011, United States (MO)	I1
Celinder, D. & Peoples, H.	*Stroke patients' experiences with Wii Sports® during inpatient rehabilitation*	2012, Denmark	I2
Deutsch, J. E., Robbins, D., Morrison, J. & Guarrera Bowlby, P.	*Wii-based compared to standard of care balance and mobility rehabilitation for two individuals post-stroke*	2009, United States (NJ)	I3
Fritz, S., Peters, D., Merlo, A. & Donley, J.	*Active video-gaming effects on balance and mobility in individuals with chronic stroke: A randomized controlled trial*	2013, United States (SC)	I4
J oo, L. Y., Yin, T. S., Xu, D., Thia, E., Chia, P. F., Kuah, C. W. K. & He, K. K.	*A feasibility study using interactive commercial off-the-shelf computer gaming in upper limb rehabilitation in patients after stroke*	2010, Singapore	I5
Kim, E. K., Kang, J. H., Park, J. S. & Jung, B. H.	*Clinical feasibility of interactive commercial Nintendo gaming for chronic stroke rehabilitation*	2012, South Korea	I6
Peters, D. M., McPherson, A. K., Fletcher, B., McClenaghan, B. A. & Fritz, S. L.	*Counting repetitions: An observational study of video game play in people with chronic poststroke hemiparesis*	2013, United States (SC)	I7
Rajaratnam, B. S., Tim, X. T., Elsa, A. Y. H., Ng, K. H., Su, Y., Wilson, W. Y. H. & Teo, S. T. S.	*Wii-rehab to enhance balance among patients with stroke*	2011, Singapore	I8
Saposnik, G., Teasell, R., Mamdani, M., Hall J., Mcllroy, W., Cheung, D., Thorpe, K. E., Cohen, L.G. & Bayley, M.	*Effectiveness of virtual reality using Wii gaming technology in stroke rehabilitation: A pilot randomized clinical trial and proof of principle*	2010, Canada	I9

Table 2 shows that the 9 included publications are comparatively recent as they were all published in the period from 2009 till 2013. Four of the 9 included studies were published in the United States, 2 studies were published in Singapore; the remaining studies were published in Canada, Denmark and South Korea. There were no overlaps found in the authors of the 9 publications.

The results of this present review are presented in *Table 3*, which is the data extraction table and extends over the next 6 pages. The presentation of the results resembles the five categories that were used for the extraction of relevant data. Following *Table 3*, the most important findings in each of the five categories will be summarized.

Table 3. Data extraction table

Article	Study characteristics	Intervention characteristics	Evaluation of outcome measures	Major advantages	Limitations
I1: Alankus et al., 2011	**Purpose of study:** Investigating important human factors in home deployment of Wii-based stroke rehabilitation. **Study design**: Case Study **Participants:** 1 female participant, aged 62 who was 17 years post-stroke; had impairments in the upper extremity of the left side of her body; had received several months of in- and outpatient therapy before. **Measuring instruments:** Data were obtained by interviews, notes taken by the participant, game logs (recordings of in-game motions) and two motion assessment scales (ARAT, RPS).	**Intervention set-up:** Participant played therapeutic games over a 6 week period in home setting and had weekly meetings with an occupational therapist; intervention was designed to resemble standard outpatient occupational therapy. **Game characteristics:** Subject played 3 customized motion-based games, adjusted for home setting; games were played through motions that are similar to standard exercises in occupational therapy; motions were measured by a webcam and two Wii remotes which were applied to the participants arms.	**Evaluation of outcome measures, according to the authors:** Significant improvements of motor functions found in RPS scores and game log data; results were supported by qualitative data. **Evaluation of outcome measures, according to Morrison et al. (2012):** More effective, because improvements were found in the majority of outcome measures.	Participant showed improvements in motion range and precision of motions; improvements in motor functionality were found, though participant was in the chronic stage post-stroke; participant was able to transfer improvements made during the intervention to daily tasks; increased patient motivation to go on with therapeutic exercises.	**Limitations of study design:** Study focuses on one patient only, - makes it difficult to generalize intervention outcomes - makes it difficult to create general guidelines for intervention design; participant was 17 years post-stroke, while general intervention designs should focus on the critical phase post-stroke (first year after incident). **Limitations met in the intervention:** Improvements, found in the recorded data of the game logs were not persistent over the whole intervention period.
I2: Celinder & Peoples; 2012	**Purpose of study:** Exploring stroke patients experiences with the Wii as an addition to standard occupational therapy. **Study design:** Pre-post test **Participants:** 9 stroke patients, aged 51-93; 6 male, 3 female; all receiving inpatient therapy in stroke unit; varying in age, gender and severity of impairments. **Measuring instruments:** Qualitative triangulation, working with semi-structured interviews and field notes; subsequent open-coding and categorization of the obtained data.	**Intervention set-up:** 3 week intervention in a controlled clinical setting; participants played Wii games in 30 minute sessions with no more than 3 sessions per week; number of sessions altered between participants, depending on their physical condition; constant supervision by occupational therapists. **Game characteristics:** Selection of games from Wii Sports software; guidelines for use in occupational therapy were created prior to the study; no further description of game characteristics was available.	**Evaluation of outcome measures, according to the authors:** Enhanced engagement and motivation of patients during the therapy sessions; participants also experienced feelings of frustration and exhaustion due to the physical and cognitive challenges of the games. **Evaluation of outcome measures, according to Morrison et al. (2012):** No consideration due to qualitative design.	Patients made both advantageous and challenging experiences during Wii exercises; training sessions were considered as a challenging occupation and a pleasant variation to patient´s daily routine as both a rehabilitation exercise and a leisure activity.	**Limitations of study design:** Relatively small number of 9 participants; varying number of sessions that were done by each participant; possibility that important information of patient experiences were missed due to semi-structured qualitative design of the intervention measures. **Limitations met in the intervention:** Games request complex motor tasks and cognitive processes that were too challenging for a number of patients with more severe symptoms.

Article	Study characteristics	Intervention characteristics	Evaluation of outcome measures	Major advantages	Limitations
I3: Deutsch et al., 2009	**Purpose of study:** Comparing Wii-based balance and mobility program with standard of care equivalent. **Study design**: Case control report **Participants:** 2 individuals in chronic phase post stroke; had experienced stroke at least 5 years prior to study; 48 year old male participant, 34 year old female participant; both had left cerebral vascular accidents and lacked selective control and coordination in upper extremity. **Measuring instruments:** Assessed data included gait speed, gait endurance, balance, balance confidence and role of cognition; data were obtained using Gait Rite Mat, Berg Balance Scale (BBS), Dynamic Gait Index (DGI), Activities Balance Confidence Questionnaire (ABC) and Timed-Up and GO test (TUG).	**Intervention set-up:**：Four week intervention set-up in home setting with 3 one hour sessions per week (total of 12 sessions); supervision and training instructions given by clinical therapists; male participant trained using the Nintendo Wii while female participants did standard occupational exercises; participants were tested before training, after training and in a follow-up measurement, three months after training. **Game characteristics:** Selection of games from Nintendo Wii Sports and Wii Fit software, with integration of the the Wii balance board; games included boxing, bowling, baseball, ski jump, ski slalom, tightrope and aerobic activities; selected to stimulate balance, coordination and strengthening of upper extremities.	**Evaluation of outcome measures, according to the authors:** General findings indicate significant benefits from training in both Wii-based and standard of care therapy with Wii-based therapy being of greater percentual magnitude at post-test; improvements in Wii-based condition did not sustain to follow up while improvements in standard of care condition did. **Evaluation of outcome measures, according to Morrison et al. (2012):** Less effective, because the experimental condition was not necessarily as effective as the comparison group.	Wii-condition led to greater increases in post measures which leads to the assumption that it is more effective than standard of care therapy as long as the patient is engaged; Wii-based therapy was portable, easy to administer and engaging for participant; games had built in progression that increased the task difficulties and kept the participant engaged; participant consistently reported enjoyment during Wii-sessions.	**Limitations of study design:** Case report can only be generalized with limits and should be interpreted with caution; vague comparability of participants, with regard to their age, gender and physical fitness. **Limitations met in the intervention:** Wii-based therapy gave little space for customizations; game feedback was not sensitive to measure patient performance and to reflect patients improvements and required additional input from interventionist; follow-up measures indicate that participant was not able to transfer and integrate improvements made in the intervention to his daily life.
I4: Fritz et al., 2013	**Purpose of study:** Determining whether playing active videogames leads to improved balance and mobility in individuals with chronic deficits post stroke when compared to a no-treatment control group. **Study design**: Single blind randomized controlled trial	**Intervention set-up:** Clinical laboratory trial; 5 week period with 50 minutes to 1 hour session; sessions were held 4 days a week; participants were randomly assigned into an experimental and a control group; groups were matched so they would both include important prognostic factors; experimental group played games under the supervision of intervention assistants and did not receive any further physical therapy; control group received no treatment at all.	**Evaluation of outcome measures, according to the authors:** No statistically significant differences found between experimental and control group in any of the used outcome measures; experimental group showed insignificant but consistent higher within-group effect in post and follow-up measures.	Although the effect size of the gaming intervention is small, the within group effects indicate that playing video games as used in the intervention may have a positive effect on the balance and mobility of the user.	**Limitations of study design:** Small sample size; no consideration of effects of the two different gaming consoles, regarding game design and feedback provided through the systems; variations in game play due to subject preferences, functional level and motivation; varying supervising personnel.

Article	Study characteristics	Intervention characteristics	Evaluation of outcome measures	Major advantages	Limitations
I4: Fritz et al., 2013 (continued)	**Participants:** 30 subjects with a mean age of 63.5 years; all were at least 6 months post stroke; all had unilateral paralysis in their lower extremities; had ability to stand with minimal physical assistance. **Measuring instruments:** 7 standard motion assessment scales: Fugl-Meyer Assessment of Upper Limb Motor Funtion (FMA), Berg Balance Scale (BBS), Dynamic Gait Index (DGI); Stroke Impact Scale (SIS), 6-minute walk test; 3-minute walk test; Timed-Up and Go Test (TUG).	**Game characteristics:** Use of two commercially available gaming consoles: Nintendo Wii and Playstation 2; selection of games from the Wii Sports and the Wii Fit software as well as from Playstation Eye Toy 2; games were chosen by participant interest and to encourage independent operation.	**Evaluation of outcome measures, according to Morrison et al. (2012):** Ineffective, because intervention was no more effective than no intervention control group		**Limitations met in the intervention:** Berg Balance Scale scores of the sampled subjects indicate only mild impairments in balance functioning; intervention should also be applied to persons with lower functional abilities.
I5: Joo, et al., 2010	**Purpose of study**: Assessing the feasibility of a commercial off-the shelf device as an adjunct to conventional stroke therapy for patients with upper limb weakness. **Study design:** Pilot study **Participants:** 20 stroke patients; recruited from inpatient rehabilitation; 13 male, 7 female; mean age of 64.5 years; participants were less than 3 months post-stroke and had moderate impairments in their upper limb motor functions. **Measuring instruments:** Interviewer-administered questionnaires to asses subjects experiences with intervention treatment; motion assessment scales including Fugl-Meyer Assessment of Upper Limb Motor Function (FMA), Motricity Index, Modified Ashworth Scale (MAS) and Visual Analogue Scale for assessment of pain (VAS).	**Intervention set-up:** 2 week intervention in a clinical setting in which participants played Wii games in 30 minute sessions, sessions were held 3 times a week; participants additionally received 1hour of occupational therapy and 1 hour of physiotherapy per day. **Game characteristics**: Selection of games from Wii Sports software, including boxing, bowling, tennis, golf and baseball; subjects played different games, depending on their functional capacities and preferences; participants with problems holding the Wii remotes were supported by fabric grasp assistance or by strapping Wii remotes onto their arms.	**Evaluation of outcome measures, according to the authors:** Statistically significant increases in scores of FMA and Motricity Index,; no findings in pain assessment scale; 75% of participants found Wii gaming subjectively useful; 81,3 % found it fairly to highly enjoyable; 87,5 % wanted to continue Wii therapy as an rehabilitation program; 93,8% were willing to recommend it to other patients. **Evaluation of outcome measures, according to Morrison et al. (2012):** More effective, because improvements were found in the majority of outcome measures; restricted explanatory power due to lacking control group.	Findings in motion assessment scales indicate that subjects had better upper limb motor power and function than before the study, which may at least partially be a result from Wii exercises; majority of participants experienced Wii gaming as an entertaining and useful adjunct to their standard therapy exercises.	**Limitations of study design:** Comparatively small sample size; no control group or condition; subjects were receiving Wii therapy and conventional therapy at the same time, which makes assumptions about the effectiveness of Wii therapy doubtable; chance that improvements resulted from spontaneous recovery as patients were evaluated in an early stadium post-stroke. **Limitations met in the intervention:** 2 participants complained of lethargy and fatigue after first session and withdrew; participants encountered problems in holding Wii remotes due to poor hand functionality; necessity of supervision; participants were unable to understand the language used in the game due to deficits in their knowledge of the English language

Article	Study characteristics	Intervention characteristics	Evaluation of outcome measures	Major advantages	Limitations
I6: Kim et al., 2012	**Purpose of study**: Investigating effectiveness of Wii-gaming on postural control, motor function and functional independence of chronic stroke patients. **Study design:** Randomized controlled trial **Participants:** 20 stroke patients with a mean age of 41.3 years; all taking part in inpatient therapy and diagnosed with stroke beforehand; varying forms of functional impairments; participants were able to maintain in an upright position without assistance. **Measuring instruments:** Data were obtained by using 3 standard motion assessment scales: Postural Assessment Scale (PASS), Modified Motor Assessment Scale (MMAS) and Functional Independence Measure (FIM).	**Intervention set-up:** 3 week intervention in clinical setting; participants were randomly assigned into an experimental and a control condition; subjects from both groups received general exercise program for 30 minutes with additional electrical stimulation of the impaired extremities; subjects of the experimental group were instructed to play Wii-games in 30 minute sessions, while subjects of control group did not play digital games; 3 sessions per week (total of 9 sessions); sessions were held under supervision of occupational therapists. **Game characteristics**: Number of games was confined to two games from the Wii Sports software: Wii Boxing and Wii Tennis; each game was played for 15 minutes per session; participants were informed of their game scores to ensure active participation.	**Evaluation of outcome measures, according to the authors:** Significant increases in the PASS and the MMAS scores of both the experimental and the control group, scores of the experimental group were significantly higher than scores of control group; no significant differences were found in the FIM scores of both groups. **Evaluation of outcome measures, according to Morrison et al. (2012):** More effective, because improvements were found in the majority of outcome measures and the experimental group scored significantly higher than the control group.	Feedback, provided by game scores enhances self awareness and active participation of patients; patients, who were not able to perform sports, due to their functional impairments have the possibility to reproduce sportive motions in virtual environments.	**Limitations of study design:** Limited informative value due to comparatively small sample size **Limitations met in the intervention:** A number participants experienced loss of balance, which makes supervision necessary during Wii-exercises; participants with more severe impairments had difficulties in holding the Wii-remote and needed support by fabric grasp assistance or by strapping Wii-remotes onto their arms.
I7: Peters et al., 2013	**Purpose of study**: Documenting and comparing the number of repetitions made in game-based stroke therapy approaches. **Study design:** Observational study **Participants:** 12 participants with a mean age of 66.8 years; more than 6 months post-stroke; all participants had an unilateral paralysis due to stroke. **Measuring instruments:** Observations through video recordings, which were held during the whole intervention process; researchers counted functional repetitions made during the exercises.	**Intervention set-up:** 5 week intervention in clinical laboratory setting**;** participants were randomly assigned into 2 groups with 2 different gaming conditions; in 4 sessions per week, each lasting 1 hour, they were instructed to play games under the supervision of intervention assistants. **Game characteristics**: One group used the Nintendo Wii; the other group used the Playstation 2; Nintendo Wii group played games from the Wii Sports and the Wii Fit software, integrating the Wii Balance Board when needed, while Playstation 2 group played games from the Eye Toy 2 software.	**Evaluation of outcome measures, according to the authors:** Comparing the number of repetitions showed that the Playstation 2 group made a statistically significant greater number of repetitions than the Wii group; both gaming groups made a significantly greater amount of repetitions, compared to reports from traditional therapy approaches. **Evaluation of outcome measures, according to Morrison et al. (2012):** No consideration due to observational study design.	Comparing the number of repetitions made in both gaming groups with the number of repetitions made in traditional therapy approaches leads to the assumption that game-based therapy designs promote patient motivation and active participation which leads to increases in the total number of functional repetitions.	**Limitations of study design:** Limited inter-rater reliability due to subjective classifications of movements as repetitions; study focused on quantity and not quality of movements; games and session times varied between participants. **Limitations met in the intervention:** Number of repetitions made in the gaming exercises is still small in comparison with the amount of active repetitions that animal studies suggest is needed to promote a reorganization of the impaired brain areas.

Article	Study Characteristics	Intervention Characteristics	Evaluation of outcome measures	Major Advantages	Limitations
I8: Rajaratnam et al., 2011	**Purpose of study**: Evaluating benefits of incorporating Wii-therapy into post-stroke balance training compared to conventional rehabilitation design. **Study design:** Randomized controlled trial **Participants**: 15 participants; all diagnosed with stroke beforehand; recruited from inpatient therapy; all above 45 years of age. **Measuring instruments:** Outcome measures assessed functional independence and mobility, risk of falls and ability to maintain upper-limb stability; included assessment scales were the Modified Barthel Index (MBI), Timed up and Go test (TUG) Functional reach test (FRT) as well as a verbal survey to evaluate patient motivation.	**Intervention set-up:** Participants were randomly allocated into experimental and control group; each group ran through 15 intervention sessions, each session lasted 1 hour; control group received 60 minutes of conventional rehabilitation therapy; experimental group received 40 minutes of conventional and 20 minutes of Wii-based rehabilitation therapy; supervision of both groups by therapy assistant during the whole intervention process. **Game characteristics**: Wii-therapy sessions focus on balance training; selection of games from the Wii Fit software, integrating the Wii Balance Board; no further description of game characteristics available.	**Evaluation of outcome measures, according to the authors:** Significant increases in the FRT and the MBI scores of the experimental group; no statistical differences between both groups for the three outcome measures; verbal survey found increases in patient motivation and interest in in-cooperating Wii-therapy into rehabilitation sessions. **Evaluation of outcome measures, according to Morrison et al. (2012):** More effective, because improvements were found in the majority of outcome measures and the experimental condition was at least as effective as the control group.	Wii-therapy was not superior to conventional therapy design, but provides alternative treatment options without constraining the functional outcomes of therapy; increases in patient motivation and engagement.	**Limitations of study design:** Small number of participants; no detailed description of study design and outcomes. **Limitations met in the intervention:** Not assessed, due to briefness of intervention details.
I9: Saposnik et al., 2010	**Purpose of study**: Assessing the feasibility of Nintendo Wii gaming system compared with recreational therapy in facilitating motor function of the upper extremities. **Study design:** Pilot, randomized, controlled, single-blind trial **Participants**: 22 participants with a mean age of 61.3 years; all diagnosed with stroke beforehand; less than six months post-stroke; all had impairments in their upper extremities	**Intervention set-up:** 2 week intervention in clinical setting; participants were randomly assigned into an experimental and a control condition; subjects from both groups received 1 hour of physiotherapy ad 1 hour of occupational therapy per day; subjects of the experimental group received 8 sessions of Wii-gaming with each session lasting 60 minutes; subjects of control group played recreational games (cards, bingo, "Jenga").	**Evaluation of outcome measures, according to the authors:** No serious adverse effects were found in both groups; mean total session time in recreational group was 388 minutes while mean total session time in Wii-therapy group was 364 minutes; follow-up measurements showed significant improvements in Box and Block Test in both groups; Wii-therapy group had significant increases in WMFT and non significant increases in grip strength.	No adverse effects were found during Wii-exercises, which leads to the assumption that the Wii is a safe and feasible tool for therapy; session time did not exceed session time in recreational therapy; findings in motion assessment scales indicate that Wii-therapy is effective in promoting the recovery of upper-limb motor functions.	**Limitations of study design:** Pilot study with small sample size; Wii-therapy group was significantly younger than recreational group; study was directed at assessing feasibility and not at assessing efficacy; effect measures should be interpreted with caution. **Limitations met in the intervention:** Feedback, provided by the game is not adjusted for stroke patients; participants could adapt their play to movements, which bring higher scores but are not favorable for stroke rehabilitation; patient supervision is recommended.

Article	Study Characteristics	Intervention Characteristics	Evaluation of outcome measures	Major Advantages	Limitations
I9: Saposnik et al., 2010 (continued)	**Measuring instruments:** Primary outcome measures included total session time of intervention and the number of emerging adverse effects; efficacy was measured 4 weeks after the intervention, using Wolf Motor Function Test (WMFT), Box and Block Test and Stroke Impact Scale	**Game characteristics**: Games were derived from the Wii Sports and the Wii Cooking Mamma software; each software was used for 30 minutes per session; games demanded flexions, extensions and rotation of the arms, shoulder, wrist and the fingers.	**Evaluation of outcome measures, according to Morrison et al. (2012):** More effective, because improvements were found in the majority of outcome measures and the experimental condition was at least as effective as the comparison group.		

Findings in the study characteristics

The 9 articles that are included in this review vary in their purposes and accordingly also in their study design and the used measuring instruments. Referring to the study design it was found that 4 of the 9 included studies were set up as randomized controlled trials (I4, I6, I8 & I9); 2 studies were pilot-studies that worked with simple pre- and post measurements (I2 & I5). The remaining articles included 1 observational study (I7) and 2 case studies (I1 & I3). While all 9 studies are generally directed at evaluating the feasibility of the Nintendo Wii system as a tool for stroke rehabilitation, the included interventions differ in their focus of the assessed aspects of rehabilitation therapy. I5, I6 and I9 resemble each other in their focus on assessing the efficacy of the Nintendo Wii in improving the motor functionality of the upper extremities. Similarities in the study purpose are also found in I3, I4 and I8, as all three interventions focus on determining the efficacy of the Nintendo Wii as a tool for balance and mobility rehabilitation. Two interventions had a more qualitative focus, as they were directed at assessing human factors and patients experiences in the field of Wii-based stroke rehabilitation (I1 & I2). I7 stands out from the other interventions with its focus set on counting functional repetitions during the gaming exercises. The focus of the measuring instruments was set on quantitative results in the majority of the included studies, as most of them worked with standard motion assessment scales that are generally used in recreational and physiotherapy (I1, I3, I4, I5, I6, I8 & I9). Qualitative results were mainly assessed as an adjunct to these effect measures. They were derived in the form of interviews and field notes, taken by the supervising personnel (I1, I2, I3, I5 & I8). The number of participants that was used in the assessed interventions varied between 9 and 22 participants, with exception of the two case studies, in which only one (I1) or, respectively, two people (I2) participated. The mean age of the participants was in most of the used trials around 60 years; the overall range lay between 34 and 93 years. Variations were found in the form and the severity of the functional impairments that the included participants had. General statements are hard to make as these variations were even found within participant groups in most of the 9 interventions; what was found is that most of the included studies worked with patients with mild to moderate functional impairments. Four interventions worked with stroke patients that were in the chronic stroke phase, which is defined as more than 6 months post-stroke (I1, I4, I6 & I7); the other 5 studies worked with patients who received inpatient treatment simultaneously to the Wii-interventions (I2, I3, I5, I8 & I9).

Findings in the intervention characteristics

The following findings were derived in the category of the intervention set-up: The time period in which the included interventions were conducted varied between 2 and 6 weeks. In all of the 9 studies the intervention was split up into multiple sessions, with the number of sessions varying between 8 and 20 sessions and the session times varying between 30 and 60 minutes. Seven interventions were conducted in a clinical setting (I2, I4, I5, I6, I7, I8 & I9); 2 were conducted in a home setting (I1 & I3). Except for I1, all interventions were conducted under the constant supervision of therapists or interventionists. Most of the included interventions worked with a controlled design, in order to draw comparisons of the functional outcomes of therapy. Three interventions worked with control conditions in which the participants received standard occupational therapy for the same amount of time that the experimental condition did Wii-exercises (I3, I8 & I9); two studies worked with control groups in which the participants received no training while participants in the experimental condition played Wii-games (I4 & I6). The participants of I5, I6, I8 and I9 did also generally receive additional occupational therapy and physiotherapy sessions, as they were in the critical phase post-stroke and participating in the intervention should not impede the therapeutic outcomes.

The following findings were derived in the field of game characteristics: Eight out of 9 interventions worked with games that come from the standard Wii gaming software. Most of them used the Wii-Sports software (I2, I3, I4, I5, I6, I7 & I9); interventions that focused on the balance and mobility rehabilitation also integrated the Wii-Fit software (I3, I4 & I8). I 1 was the only intervention in which participants played customized motion-based games. The played games were in most cases chosen by the interventionists in order to assure that the motions that were executed during game-play would facilitate the recovery of the specific underlying impairments of the respective subject groups. In two of the included studies adjustments had to be made, as a number of participants were unable to hold the Wii-remotes due to impairments in their hand functions (I5 & I6). They were supported through fabric grasp assistance or by strapping the Wii-remotes onto their arms.

Findings in the evaluated outcome measures

The general findings of the assessed outcome measures were predominantly supporting the feasibility of the Nintendo Wii system, with respect to both qualitative and quantitative data. Six out of 7 studies, that worked with standard motion assessment scales found significant improvements in the motor functionality of the participants in the post measurements (I1, I3, I5, I6, I8 & I9). The findings included improvements in motion range and motion precision of the upper extremities but also improved functions in balance and mobility. I3, I8 and I9 worked with control conditions in which the participants received occupational therapy instead of Wii-gaming therapy. The results of these interventions showed that Wii-based exercises are at least as effective but not necessarily more effective than their standard of care counterparts. I4 was the only exception, as no statistically significant differences were found in the functional outcomes of therapy, compared to a no intervention control group.

The qualitative outcomes correspond to the general findings as the majority of participants experienced Wii gaming as being a useful tool for rehabilitation purposes. Enhanced patient motivation, engagement and interest were found in all interventions that worked with qualitative effect measurements (I1, I2, I3, I5 & I8). In I2 it was concurrently found, that a number of patients felt frustrated and exhausted due to the physical and cognitive challenges of Wii-gaming. The other outcomes included no further adverse effects.

In order to provide comparable estimations of the effect measurements, a second evaluation of each of the respective outcome measures was done, using the criteria for defining intervention effectiveness, according to Morrison (2012). In accordance with the general findings it was estimated that 5 of the 7 studies can be defined as being more effective (I1, I5, I6, I8 & I9), 1 study as being less effective (I3) and 1 study as being ineffective (I4). No such evaluations were done with regard to I2 and I7, as the qualitative/observational design of these interventions made it impossible to classify the outcome measures.

Major advantages

The general improvements that were achieved in the functional outcomes of the Wii-gaming interventions do also account for the major advantages that come with the integration of the system. An important finding is that these improvements were also achieved in participant groups that were in the chronic phase post-stroke, as most of the recovery of impaired motor functions usually happens in the critical phase post-stroke. Follow-up

measurements indicated that participants were partially able to transfer the improvements made during the gaming exercises to daily tasks (I1, I5). The experiences that participants made, while interacting with the system were continuously positive; participants stated increased motivation and engagement during the game sessions and experienced Wii gaming as a pleasant and useful variation to their daily tasks. Games were found to be challenging but entertaining; one study stated that the used game feedback seemed to enhance the self-awareness of the participants (I6). Another major advantage lays in the absence of adverse effects. Even though several studies included instruments that were directed at the assessment of adverse effects as pain and other emerging functional deficiencies, no such effects were found on any of the participating subjects (I3, I5, I8 & I9). Further findings in the field of advantages included the portability of the Nintendo Wii system (I3), the ease of how the exercises could be administered (I1 & I3) and the fact that the length of the Wii exercises did not necessarily exceed the session times of standard occupational therapy (I9).

Limitations of study and intervention design

Most of the findings in the field of limitations were derived from the general study designs of the 9 included interventions and were connected to methodological deficits, which restricted the reliability of the conclusions of the respective studies. A major limitation that was met in all study designs was the comparatively small sample size that was used. This applied to the case studies as well as to the randomized controlled trials. A number of studies did also not include a control group, which is a problem since the included subject groups were partly in the critical phase post-stroke (less than 6 months) and received additional therapeutic treatment while they participated in the intervention program (I1, I2, I5 & I7). Therefore, it cannot be excluded that the improvements in motor functionality resulted from spontaneous recovery or from the additional treatments. Another factor that declines the reliability of the intervention outcomes is that some of the included interventions had variations in the session times and the number of session that the participants attended to (I2, I4 & I5). It was further not always ensured that the same games were played for the same amount of time, as participants were partly free to choose games, based on their individual interests and preferences (I4 & I5). Such variations restrict the comparability of the individual therapy outcomes.

Several further limitations were met during the conduction of the nine interventions. Studies that worked with qualitative results found that the standard games, derived from the Nintendo Wii software were in some cases too complex for patients with more severe symptoms (I2, I5 & I6). The integrated game feedback was also not sensitive to measure a patient´s performance and progress in a compatible way; therefore, interventionists and therapists were required to give additional feedback and inform the participants about the progresses they made over the intervention period (I3 & I9). As mentioned before, two studies encountered the problem that participants were unable to hold the Wii-remotes and needed support through fabric grasp assistance or by strapping the Wii-remotes onto their arms (I5 & I6); a number of participants had also problems in keeping their balance (I6). For these reasons, constant supervision was a necessity in all of the included interventions. Another major finding in the field of limitations was that the Nintendo Wii system itself provides little to no space for customizations or technical adjustments (I1 & I3).

Discussion

This systematic review attempted to summarize the scientific work that was done in the field of integrating the Nintendo Wii into rehabilitation interventions for stroke patients. The review included 9 publications that were derived from a systematic literature search; each intervention included a discrete intervention. The major findings that were assessed in these interventions will be discussed in the following, with respect to the four examination questions that were established at the beginning of this paper. The four established questions were directed at 1.) identifying characteristics of Wii-based interventions for stroke rehabilitation, 2.) evaluating the effectiveness of the Nintendo Wii in the context of stroke rehabilitation, 3.) naming the major advantages that come with the integration of the Nintendo Wii into stroke therapy, and 4.) naming limitations that arise in the study- and intervention design of Wii-based stroke therapy approaches.

Even though the results of this paper yielded answers to all of these questions to some extent, it is difficult to arrive at a useful conclusion about the general feasibility of the Nintendo Wii system for stroke rehabilitation purposes, if the examination questions are answered one by one. The major advantages and the limitations that come with the integration of the system are highly interconnected to the characteristics and the functional outcomes of Wii-based interventions. Therefore it was decided that the findings will be discussed in a more comprehensive way.

General findings

The findings that were derived in the field of study and intervention design showed that Wii-based interventions for stroke patients mainly focus on two specific fields of motor rehabilitation, namely on facilitating the recovery of the motor functionality in the upper extremities and on improving balance and mobility. The tools that were used for these purposes were almost exclusively off-the-shelf games, derived from the Wii gaming software. In this connection, the Wii Sports software appeared to be an expedient tool for exercises that work on the recovery of the upper extremities; included games as boxing, bowling, baseball and tennis were used for therapeutic aims as increasing motion range and motion precision of the arms and the shoulders. The Wii Fit software, on the other hand, was majorly used for balance and mobility exercises.

The derived findings in the functional outcomes of the included interventions indicate that the Nintendo Wii and the corresponding gaming software succeed in facilitating the recovery of impaired motor functions: Significant improvements in motor functionality were found in the majority of cases and comparisons with control groups that worked with traditional occupational therapy showed that the improvements, made in the gaming conditions were at least on the same level than their standard of care counterparts. The evaluation of the functional outcomes corresponds to the findings of the review of Santayayon and colleagues (2012), who also found significant increases in motor functionality in the majority of the included interventions. Even though the informative value of the referred review is questionable, the combined results of both reviews clearly indicate that the Nintendo Wii is a feasible tool for the recovery of impaired motor functions. The findings are also contrary to the suggestions of many critics of the Nintendo Wii system that were referred to in the introduction of this paper. Because the Wii was originally designed for entertainment purposes, it was suspected that the Wii gaming software was too complex and too challenging to be played by people with functional impairments and using the system could even be potentially harmful for patients post-stroke (Anderson et al, 2010). These suspicions could be refuted for the most part, as it was found that the participants interacted with the system properly, made significant improvements in their motor functionality and further showed no emerging adverse effects. It has to be accentuated that the qualitative results of a number of studies showed that patients with more severe symptoms experienced the Wii games as being too complex and felt exhausted after the Wii-exercises. Combined with the fact that the majority of the included studies did only work with patients with mild to moderate functional impairments, it is possible that the Nintendo Wii system is only feasible to a certain extent and should not be directed at patients with more severe functional impairments. On the other hand, it was found that even participants that were in the chronic phase post-stroke made statistically significant improvements in their motor functionality during the Wii-exercises. These findings are quite surprising since maximum improvements are generally achieved within the first 5 months after stroke and the recovery usually remains static after this phase (Saposnik et al. 2010). Even though these findings were derived from only 4 of the 9 included interventions, they still indicate that the Nintendo Wii holds great potential in the specific field of stroke rehabilitation that is aimed at patients in the chronic phase post-stroke.

The general findings that were derived from the qualitative results of the included interventions showed that the Nintendo Wii succeeds in enhancing patient motivation and active engagement during the therapy sessions. Patients were highly interested in the games and perceived the Wii exercises as a pleasant variation to the traditional exercises that they usually do in therapy. In this regard, the results of this paper corroborate the general findings that are made in the field of Wii-based stroke rehabilitation (Alankus et al, 2011). While the game-play uses motions that are similar to the repetitive exercises that are part of conventional occupational therapy, it is not perceived as a hindrance or a source of irritation. These findings are probably the biggest advantage that comes with the integration of the system, because the Wii offers a feasible alternative to traditional treatments that increases a patient´s motivation to do exercises as recommended and therefore maximizes the therapeutic outcomes. As problems in patient motivation are major issues of home-based rehabilitation approaches, the Nintendo Wii has great capabilities in this field.

Though, this research also yielded results that diminish the potential of the Nintendo Wii for home-deployment. The general intervention set-up of Wii-based rehabilitation approaches resembles conventional outpatient therapy in the way that the therapy program is sectioned and conducted in multiple sessions. However, these sessions were in most cases held in a clinical setting; only two studies applied the system for home use. As a number of patient groups received additional therapeutic treatment while they participated in the intervention program, it is uncertain whether the improvements in motor functionality resulted from the Wii exercises or not. Therefore, it is fair to assume that the functional therapy outcomes would have differed if the intervention had been conducted in a home-setting. Furthermore, it was found that all of the included interventions were constantly supervised by therapists or interventionists; several factors were identified that show why this constant supervision was a necessity: Even though the participants had no problems in the interaction with the Wii system, the included game feedback made it difficult for them to track the progresses they made in therapy, as it was not sensitive to measure their performance in an appropriate way. Because the system offered no options for customization, the supervising personnel had to give additional input in order to keep the participants engaged. A number of participants had also problems in holding the Wii-remotes or partially lost their balance during the exercises; these patients needed additional support as fabric grasp assistance and the supervising personnel was needed to administer the exercise session for the whole intervention period, in order to avoid physical injuries.

For these reasons, it can be indicated that it is difficult to apply the Nintendo Wii in a way so that participants can interact with the system independently. The findings in this field are in line with the problems that generally arise in home-based rehabilitation approaches, as participants need support, supervision and an adequate, individual feedback, in order to ensure active participation and facilitate the therapeutic outcomes (Alankus et al. 2011; Bateni, 2012). Because the need for medical attendance is a general limitation of such therapy approaches, an integration of the Nintendo Wii causes no additional complications in this field but offers efficient solutions for other existing problems: Conventional home-based therapy holds problems in keeping patients motivated to do their prescribed exercises as recommended and generally requires the acquisition of expensive equipment (Alankus et al., 2011; Burke et al., 2009) The acquisition of the Nintendo Wii on the other hand, is comparatively low in its costs, the use of the system is highly engaging and the system itself is, as the general outcomes of this research suggest, a feasible tool for the general recovery of impaired motor functions. Based on these findings it is estimated that a general integration of the Nintendo Wii system into both clinical and home-based therapy settings is beneficial for patients and therapists and therefore recommendable.

It has to be stated that the general findings and evaluations of this review should be regarded with some caution as the reliability of the results depends on the reliability of the included studies. Several limitations were identified in the design and the set-up of the included studies that restrict the explanatory power of the findings: First, not all of the 9 interventions included a control group. As a number of patient groups received additional therapeutic treatment during the intervention period, it cannot be safely assumed that the improvements in the functional outcomes are a result of the Wii-exercises. Furthermore, it was found that all of the included studies worked with comparatively small sample sizes, which is understandable since wide scaled research in the field of stroke rehabilitation demands great expenditures in time, money and personnel and stroke patients need to be treated with extra caution. However, the small sample sizes diminish the significance of the functional results and make it difficult to generalize the derived findings.

Because the overall results of this review are consistent and correspond to the findings of other research, it is reasonable to assume that the impact of these limitations is still within an acceptable scope.

Methodological considerations

While the findings of this systematic review contribute to the scientific work that is done in the field of Wii-based stroke rehabilitation interventions, the used methodological approach does include several limitations, which are primarily connected to the systematic search strategy that was used in this research. The search strategy was based on search constructs, which were designed in an early stage of the course of this research. At the point that the constructs and the respective keyterms were assembled, our research team had little to no experiences with games that are used in healthcare. Therefore, it is possible that important terms were missed and, as a consequence specific fields of health related games were not included in the findings of this search. Similar problems were met during the screening phases, as the eligibility criteria that were used were partially too undefined and left room for subjective interpretations. These eligibility criteria were handled with regard to the content of the titles and abstracts; therefore, it is probable that a multitude of studies was excluded, while their actual content was suitable for the framework of games and game elements in healthcare.

The search strategy that was used in this research does also usually include a last phase where the articles that emerge from the abstract screening phase are screened one more time with regard to the eligibility of the full-texts. Because this would go beyond the scope of this bachelor degree program, it was decided to skip this phase and to base this review on the outcomes of the abstract screening. However, the abstracts did not always offer sufficient information to certainly conclude that the respective articles were not relevant for the purpose of this review. In order to avoid unwarranted exclusions, the researchers did work as accurate as possible during this screening phase; still, it cannot be ruled out that such exclusions have occurred. The way how the data of the 9 included interventions were extracted does also hold some possible limitations, as information was only included if it matched the established categories for data extraction. Because the 9 included interventions varied in the density of the included information, it is possible that important information was missed and, on the other hand, unimportant information received too much attention. As this review tried to give an objective and comprehensive insight into the field of Wii based rehabilitation approaches without weighting the results of the included interventions, such problems cannot be avoided.

The qualitative approach that was handled during the data extraction is also the major strength of this research, because the focus of the results was not set on just one specific field but on multiple fields. Much of the scientific work, that is done in the field of Wii-based stroke rehabilitation only focuses on the functional outcomes of therapy and includes no

information on how Wii-based interventions are actually designed. This review did an attempt to add to the scientific field of Wii-based stroke rehabilitation, by integrating important information about the study- and the intervention design and by naming the most important advantages and limitations that come with Wii-based therapy interventions. These findings will hopefully contribute to future intervention designs and the creation of general guidelines for Wii-based stroke rehabilitation approaches.

Clinical implications and future research

The general findings of this review suggest that the Nintendo Wii is a feasible tool for stroke rehabilitation purposes in both clinical and home-based therapy settings. The functional outcomes of Wii-based therapy can keep up with traditional approaches and the system is successful in enhancing motivation and active participation of patients during exercises. It was further found that the Nintendo Wii holds some potential in the field of rehabilitation therapy that is directed at patients in the chronic phase post-stroke. The use of the Nintendo Wii holds limitations in the field of home deployment as it requires constant attendance by healthcare professionals, which undermines it´s potential as a rehabilitation tool that allows patients to continue therapy in their home-environment independently. The advantages that come with the integration of the Nintendo Wii into stroke therapy do still outweigh its limitations to a great extent. Therefore, it is suggested that the system is feasible for a wide scaled integration into stroke therapy. However, these implications need to be confirmed by comprehensive work that comprises a larger scale of studies, directed at this field.

General recommendations for future research can be made in the way, that more studies are needed that include a larger sample size and a greater variety of demographics and functional impairments, as all of the interventions that were included in this review worked with comparatively small sample sizes and it still uncertain how Wii-based interventions affect the recovery of patients with more severe symptoms. The included studies did also work with a wide range of measures that were directed at different outcomes of therapy. Future research in the field of Wii-based stroke rehabilitation should focus on smaller numbers of standardized outcome measures in order enable comparisons and generalizations of the findings.

Acknowledgements

The author of this paper would like to thank the first and second supervisor Dr. S.M. Kelders and Dr. R. van der Vaart for their great support and guidance throughout the course of this research. Further, the author would like to acknowledge the cooperation with A. Ern, who has been a great partner and companion and made the intense phases of the research process more delightful.

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