Rehabilitation Gaming

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Serious Games for Healthcare:

Applications and Implications

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Chapter 3
Rehabilitation Gaming

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ABSTRACT

A recent innovation in rehabilitation is the use of serious gaming to train motor, cognitive, and social abilities. The main advantages of rehabilitation gaming are related to the motivation to engage in rehabilitation, the objectivity of rehabilitation measurements, and the personalization of the treatment. This chapter focuses on the use and effectiveness of serious gaming in rehabilitation and illustrates the possibilities and strengths in this new and exciting work field. Furthermore, a review of the literature and examples of rehabilitation games are presented. The state-of-the-art technologies and directions for future research are also discussed. Rehabilitation gaming has great potential for today's and future health care, and despite the research gaps, there is increasing evidence that gaming can positively contribute to the rehabilitation and recovery process.

INTRODUCTION

Until recently, both the media and scientists focused mainly on the negative consequences of digital gaming like aggressive behaviour (Ferguson, 2007; Anderson & Bushman, 2001). Fortunately, the tide has turned, and the focus has shifted to the positive effects of digital game play and the powerful, persuasive, and motivating elements of digital games are-aside for entertainment purposes-used for the better: training, learning, and skill acquisition. Digital games that are specifically developed for these purposes are called serious games (Boyle, Connolly, & Hainey, 2011). Serious games have an explicit and carefully thought-out educational purpose and are not intended to be played primarily for amusement (Abt, 1970). Serious games have been recognized and are employed in various fields like the military and education, but have found increasing interest from the health domain, particularly in rehabilitation, partially due to the rise of low-cost embodied gaming.

The benefits of rehabilitation can be translated into a higher quality of life for both patients and their families. In addition, rehabilitation can result in lower costs for additional health care and higher productivity as patients may return to the workforce much faster. Furthermore, health care

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innovations that enhance rehabilitation could increase the benefits even more. One of the latest innovations in rehabilitation is the use of serious games for cognitive, psychological, motoric, and social rehabilitation. Rehabilitation gaming is a form of mediated rehabilitation, similar to telerehabilitation which is mediated by videophone (see, Popescu, Burdea, Bouzit, & Hentz, 2000) and rehabilitation mediated by Virtual Reality (VR) (see, Difede & Hoffman, 2002; Ready, Gerardi, Backscheider, Mascaro, & Rothbaum, 2010). The main advantages of mediated rehabilitation compared to traditional rehabilitation, in particular game-based rehabilitation, are related to the *motivation* to engage in rehabilitation, the *objectivity* of rehabilitation measurements, and the *personalization* of the treatment.

There is little doubt that digital games are highly *motivating* to play, because of the interactivity and feedback mechanisms that can increase the player's self-efficacy and mastery. Self-efficacy is the belief in one's ability to succeed in specific situations and it determines whether coping behaviour will be initiated, how much effort will be expended, and how long it will be sustained in the face of obstacles and aversive experiences (Bandura, 1977). In addition to enhanced self-efficacy, players can reach a state of optimal experience, which is called 'flow' (Csikszentmihalyi, 1975; Csikszentmihalyi & Csikszentmihalyi, 1988). When players are fully engaged with the task at hand, actions are performed automatically and an optimal balance between skills and challenge is reached. Digital games in rehabilitation can motivate players to continue their training activity and advance in their skills while being 'in the zone.' In contrast, conventional rehabilitation can be a tedious exercise by performing the same movements over and over again and even highly motivated patients and therapists can become unmotivated and tired after numerous repetitions of the same movement. Rehabilitation that is mediated by means of technology can track and translate small unnoticeable advancements in the clients' recovery process into observable (in-game) progresses like scores, bonuses, and level advancements. A rehabilitation game can provide a client with positive feedback when most appropriate, which should preferably be provided on learning goals rather than performance goals (Dweck, 1986). In addition to game related advancements, rehabilitation games, controlled by e.g., a haptic feedback glove like the Rutgers II (see, Popescu et al., 2000), can monitor *objectively* over time the number of repetitions, strength levels, and extension distance. Therapists are highly trained in these measurements; however, the measurements can deviate between therapists and/or may sometimes be obstructed from view. Objective precise measurements and in-game scores can be used as input for the game dynamics and feedback mechanisms. Most game worlds can already be easily adapted by changing the scenery, complexity, avatar, controls, etc. A patient or therapist can use these variables to easily *personalize* the game and make it compatible with the clients' abilities and needs. Not only the patient or therapist can adapt the rehabilitation game, the game itself can also automatically adapt to the clients' progress. For example, decreasing in-game scores which reflect a decline in the rehabilitation phase can be used to adapt the difficulty level and/or in-game speed to lower values to continue progress and possibly increase the clients' motivation to carry on rehabilitating. The whole virtual environment, including the characters, scenery, and even the storyline can be adapted to the player's specific needs and abilities. The flexibility of virtual environments provides a considerable advantage compared to conventional rehabilitation.

Rehabilitation gaming has great potential for today's and future health care. This chapter will focus on the use and effectiveness of serious gaming in rehabilitation. The chapter is not to be exhaustive, but illustrates the possibilities and strengths in this new and exciting work field. Furthermore, the chapter provides a review of the literature, examples of rehabilitation games, technologies in rehabilitation gaming, and directions for future research.

REHABILITATION: FOCUS AREAS

In the following sections, we present the research on rehabilitation gaming in the areas of cognitive, psychological, physical, and social rehabilitation.

Cognitive Rehabilitation: The Role of Digital Games in Cognitive Function

In the latest years, the effectiveness of brain training games, like Nintendo's Brain Training by Dr. Kawashima or Big Brain Academy, and the presence of the 'use it or lose it' hypothesis in our daily life has been assumed as a truth or 'folk psychology.' Beyond the evidence of cognitive training interventions such as the one implemented in the ACTIVE study (Willis et al., 2006), computerized cognitive training and more specifically, the research on the area of digital games targeting cognitive functions is still in its early stages (see also, Salthouse, 2006). Nevertheless, we would like to stress that stimulation and training goes beyond the notion of 'use it or lose it,' which according to Goldberg (2005) should rather be rephrased to 'use it and get more of it.' Digital games that try to provide stimulation and training for the aging or damaged brain should broaden and challenge the players' knowledge and skills.

Digital Games for the Improvement of Attention

In a work of 2003, Green and Bavelier demonstrated that digital game play enhances the overall capacity of the attentional system (the number of items that can be attended), the ability to effectively deploy attention over space, and the temporal resolution of attention (the efficiency with which attention acts over time). Expert action digital game players were found to outperform non-gamers on tasks measuring the spatial distribution and resolution of visual attention, the efficiency of visual attention over time, and the number of objects that can be attended simultaneously. On a similar work, Castel, Pratt, and Drummond (2005) examined the similarities and differences between digital game players and non players in terms of the ability to inhibit attention from returning to previously attended locations, and the efficiency of visual search in easy and more demanding search environments. People who played digital games showed overall faster response time to detect targets, and overall faster response time for easy and difficult visual search tasks compared to non players, which can be attributed to faster stimulus-response mapping. It is likely that these findings may have implications to real life situations. People may benefit from digital game play in their experience in daily life, e.g., in complex and attention demanding tasks like driving in a car or way finding in an airport. As Green and Bavelier (2006) state, players seem to show a reduced cost of divided attention and thereby could outperform non players at detecting items in the periphery, like a child chasing a ball toward the street while driving. Digital game play has the potential to enhance attentional processes, which are highly relevant in successfully performing the Activities of Daily Life (ADL).

Spatial Ability

In visual tasks, spatial ability is the ability to estimate, judge, or predict the relations among figures or objects in different contexts (Elliot & Smith, 1983). Digital game play-in particular first-person shooters (FPS)-can have a positive effect on this ability. Feng, Spence, and Pratt (2007) studied the relation between digital game play and spatial ability and varied the genre of the game in an experiment. The experimental group in their study played a three-dimensional (3D) FPS game called 'Medal of Honor-Pacific Assault' (Electronic Arts) during a training session of 10 hours. The control group played a non-action game called 'Ballance' for the same amount of time. Ballance is a 3D puzzle game in which the player has to steer a ball through a hovering maze of paths and rails with various obstacles. It was found that the training with the FPS action game resulted in substantial enhancements in spatial attention and mental rotation. Females benefited more than men, as such that prior gender differences were reduced or eliminated. On a later work, Barlett, Anderson, and Swing (2009) stated that the ability to mentally rotate or arrange objects in space is related to a number of general learning tests and paradigms. According to the authors, research has shown that digital game play is related to this spatial ability (Barlett et al, 2009). Interestingly, research from Ferguson (2010) showed that playing action games has a more positive effect on visuospatial cognition than playing Tetris, developed by Alexey Pajitnov, which was primarily designed for mental rotation tasks. It is suggested that the findings are probably due to the fast action commonly found in a FPS game (Ferguson, 2010).

Digital Games for Reasoning

Basak, Boot, Voss and Kramer (2008) recently studied the effect of training on a real-time strategy game (Rise of Nations, by BigHuge Games, & Microsoft Game Studios) on older adults' performance in a wide-range of executive control tasks, such as short-term memory, working memory, task switching, and inhibition. Significant benefits were found after 23.5 hours of strategy-based gaming on executive control functions following training. The well performed study was one of few that showed enhancements of cognitive functioning of older adults by playing digital games. The results from a recent study of Owen et al. (2010), published in Nature, suggest that improved cognitive functioning by brain training games only hold for the cognitive tasks that are trained. They found no transfer to more general tests of cognition, even when those tasks were closely related to the trained task. Owen et al. (2010) used a large sample of 11,430 participants ranging from 18 to 60 years of age, yet, no seniors were included who could potentially benefit the most from playing brain training games.

Improving Visual Memory with Digital Games

Ferguson, Cruz, and Rueda (2008) examined whether visuospatial recall of abstract and common objects was related to gender, and whether there was influence of experience with digital game play on their visual memory recall performance. In the study, both the previous exposure to digital games and the exposure to violent digital games were included. The total time spent playing, as well as exposure to violent digital games, predicted increased visual memory recall performance, leaving the door open for the study of positive effects of games with violent-related content (e.g., Re-Mission game for cancer education, Kato et al., 2008, see this chapter). In relation to this, a meta-analytic review was developed by Ferguson (2007), who found that publication bias was a problem for studies of both aggressive behaviour and visuospatial cognition. Once corrected for a publication bias, studies of digital game violence provided support for a higher visuospatial cognition. Additional research is necessary, since the body of evidence is small and effect studies are lacking.

One Step Beyond: Last-Generation Console Gaming for Intervention with Dementia

In the field of dementia rehabilitation, increasing evidence is emerging focusing on technology based solutions versus traditional paper-and-pencil rehabilitation techniques. Boulay et al. (2009) tested the MINWii, a music therapy game to be used in the treatment of people with Alzheimer's disease. The game allowed the patients to improvise or play songs of their choice by pointing with a Wiimote Pistol at a virtual keyboard that was displayed on a TV set. A Nintendo Wiimote Pistol is a hand light gun grip in which a standard Wiimote can be placed as such that it resembles and operates as a pistol. Seven patients with Alzheimer's disease participated in the study of

Boulay et al. (2009) and it was shown that the MINWii game was usable and an instant mastery was shown and even a learning effect. The game fostered positive interactions with the caregivers and elicited powerful reminiscence.

Recently, Cherniack (2011) described VR based applications in the identification and treatment of older people with cognitive disorders. According to the author, VR can in potential offer an assessment of function and could enhance the ability to perform activities of daily living in patients with dementia, stroke, and Parkinson's disease. However, scientific evidence is still limited and the performed studies have been small and unblinded. In order to throw some more light over this topic, a recent study from Fernández-Calvo et al. (2011) assessed the efficacy of cognitive training using Nintendo's Big Brain Academy (BBA)-a brain training game-compared to the Integrated Psychostimulation Program (IPP), which is a classical paper-and-pencil cognitive therapy, for patients who are diagnosed with mild Alzheimer's disease. In total, forty-five patients were randomly assigned to three experimental conditions: intervention with BBA; intervention with IPP; and no treatment (NT). Interestingly, from the results it was shown that the group trained with the BBA suffered a lower cognitive decline than the IPP and NT groups. Moreover, the BBA group showed a significantly higher reduction of depressive symptomatology when compared to the IPP and NT groups. The study of Fernández-Calvo et al. (2011) showed the strength and potential of digital games in health treatment, in particular because an off-the-shelf game like BBA outperformed a classical therapy in the training of people with a cognitive impairment.

DIGITAL GAMES' CONTRIBUTION TO PSYCHOLOGICAL HEALTH AND TREATMENT OF PSYCHOLOGICAL DISORDERS

Impact on Self-Efficacy

Griffiths (2002) reported on the educational benefits of digital games, and discussed the study of Thomas, Cahill, and Santilli (1997). In that study, an interactive computer program called 'Life Challenge' was used as a tool to enhance adolescents' perceived self-efficacy on HIV/AIDS prevention programs. To support the enhancement of self-efficacy, Thomas, Cahill, and Santilli (1997) used a prevention program that was based on a time travel adventure game format. In the game, a player can choose a co-player on a journey to various places (e.g., a medieval castle or a Jazz club in space). Players will have to negotiate in tasks related to HIV and Aids related high-risk behaviours. Significant gains were achieved in factual information about safe sex practices and in self-efficacy scores. Despite these positive effects, it is unclear which mechanisms contribute to the success of the prevention program. To gather an insight in the mechanisms that work, fundamental research is needed with small differences in the manipulations, e.g., solely vary the co-player, the game environment, etc.

Another self-efficacy study showed improved treatment adherence and cancer-related self-efficacy and knowledge after an intervention with the 'Re-Mission' game, which can be seen in Figure 1. Remission in cancer treatment means that the treatment is effective for a period of time. The digital game addressed the issues of cancer treatment and care for teenagers and young adults (Kato, Cole, Bradlyn, & Pollock, 2008). The Re-Mission's game play includes destroying cancer cells and managing common treatment-related adverse effects such as bacterial infections, nausea, and constipation by using chemotherapy (Kato et al., 2008). To win, players control a nanobot

Figure 1. Image from the digital game Re-Mission (© 2006, HopeLab Foundation, Inc. Used with permission)

named 'Roxxi' to ensure strategically that virtual patients engage in positive self-care behaviours, like taking oral chemotherapy to fight cancer cells, and taking antibiotics to fight infection.

Treatment of Anxiety and Anxiety Related Disorders

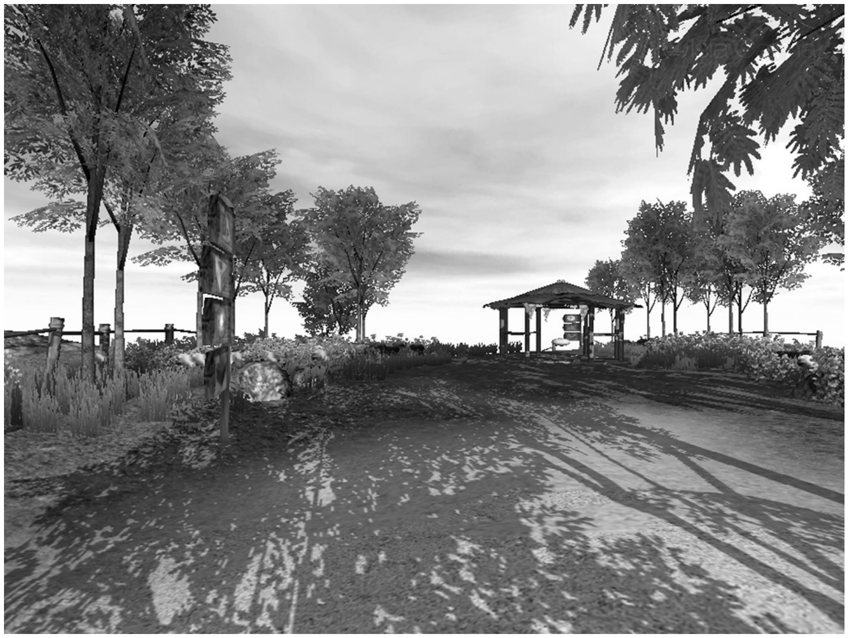
Exergames are games that combine play and exercise with the goal to motivate players to engage in physical activity (Bogost, 2005) and have been used to improve depressive symptoms and mental health related quality of life (Rosenberg et al., 2010). In the study of Rosenberg et al. (2010), positive effects were found after a twelve week intervention, with three 35-minute sessions a week, using Nintendo's Wii Sports. Positive effects have also been found of gaming on anxiety treatment in a study of Patel et al. (2006). In this study, 112 children participated who were undergoing general anaesthesia for elective surgery. The patients were assigned to one of three groups; parent present; parent present and sedative medication, and parent present and digital game distraction by means of game play on the Gameboy (a handheld digital game device developed by Nintendo). The results showed that digital game distraction decreased anxiety from the baseline measurement, while the other groups showed a significant increase in anxiety. The authors conclude that digital game play on a handheld can be provided as a low cost, easy to implement, and effective means to decrease the anxiety before surgery and during anaesthesia. Another noteworthy project to treat anxiety by means of gaming is 'Relax to Win' of the MindGames team at Media Lab in Europe (McDarby, Condron, & Sharry, 2003). 'Relax to Win' is a two-player competitive game which uses biofeedback to control a dragon in a race. The more a player relaxes, as measured by the galvanic skin response (GSR), the faster the dragon moves, i.e., the player wins by learning to relax. According to the authors, the game has proved to be engaging to children and motivated them to become curious on how they relax and to learn new relaxation skills. Future research and development in relaxation gaming should rather add additional measurements besides GSR. A combination of measurements is preferred because some people have little variation in their GSR between relaxation and stress, while others always have a high conductive skin response, irrespective of their emotional status. Furthermore, an increase in the measured level of conductance cannot explain the type of emotion that is triggered, and therefore future research could combine ECG measurements, heart rate variability, facial expressions, etc. as a more valid indicator of relaxation.

In a review of Wilkinson et al. (2008), there is some evidence that digital games can also contribute to reduced Attention Deficit Hyperactivity Disorder (ADHD) symptoms, and a report on a study by Pope and Palsson (2001) about the development of a NASA patent on ADHD intervention by biofeedback modulated 'off-the-shelf' digital games. The participating children played a number of games on the Sony Playstation, varying from skateboarding to adventure games. Overall, they had 40 sessions, lasting approximately one hour per session with about an average of two sessions per week. No difference was found in the efficacy of the intervention to reduce inattention and hyperactivity compared to conventional interventions. Yet, the participants stated that game intervention was far more enjoyable than existing methods to reduce ADHD symptoms. In 2011, Nesplora (see, www.nesplora.com) have developed AULA, an evaluation test which employs VR to facilitate diagnosis of Attention Deficit Disorder with and without Hyperactivity. The AULA system analyzes the behaviour of a child in the context of a virtual classroom. The tool is perceived initially as a game, in which the child performs a task while typical distracters of a classroom are presented to him or her, which is demonstrated in figure 2.

The AULA test evaluates factors determining the existence of ADHD, such as sustained attention, impulsivity, divided visual and auditory attention, excessive motor activity, and a tendency to distraction (by means of a movement sensor). After the test, the system returns an evaluation report that helps the clinician perform a more accurate and reliable diagnosis. Nesplora is also working on 'ISLA CALMA,' which will be commercialized in 2012. ISLA CALMA is an introspection of an island, seen in Figure 3, in which the player must explore and give life to some scenarios that need the interaction with the user; in this way, participants get immersed in a situation demanding their attention, thus minimizing situations of pain and anxiety. The Island will be marketed to be used in dental clinics or in surgical procedures in hospitals, as well as for relaxation techniques' training and for post-traumatic stress disorder treatment.

Figure 2. Image from AULA software (© 2011, Nesplora S.L.; Used with permission)

Figure 3. Image from ISLA CALMA anxiety and pain distracting software (© 2011, Nesplora S.L.; Used with permission)



People who suffer from Post-Traumatic Stress Disorder (PTSD) have usually experienced a highly traumatic 'extraordinary' event with human death(s) involved, like a military battle or terrorist attack. PTSD is generally treated by means of imaginal exposure therapy; however, many patients are unable to regenerate the traumatic event and avoid the trauma, as demonstrated by Difede and Hoffman (2002). These authors showed the effectiveness of VR exposure therapy for PTSD in a case study with a patient who suffered from 'World Trade Center' PTSD, which was triggered by an intense experience or repeated exposure to the WTC attack in New York (September 11, 2001). The computer-generated environment consisted of lower Manhattan (New York), and the event she re-experienced was the WTC attack. The patient in the study failed to improve after traditional imaginal exposure therapy, yet, after the VR exposure therapy, depression was reduced by 83 percent and PTSD symptoms by 90 percent.

In the field of early interventions on PTSD, Holmes et al. (2009) performed a study in which participants played TETRIS half an hour after viewing a traumatic video. They expected that game play interference with trauma memory consolidation processes would reduce flashback frequency. In order to reach this objective, 40 participants were presented with a 12 minute film of traumatic scenes of injury and death. After this, the participants were randomly assigned to an experimental or control condition. The experimental participants played TETRIS for 10 minutes while control participants sat quietly during the same amount of time. Flashbacks were monitored with a diary, and results indicated that the participants in the TETRIS condition produced a significant reduction in flashback frequency over one week, and these results were in agreement with a clinical measure of PTSD symptomatology. These results imply that non-invasive cognitive interventions like playing the TETRIS game may be used at a crisis intervention after traumatic events.

PHYSICAL REHABILITATION: THE ROLE OF DIGITAL GAMES IN PHYSICAL RECOVERY

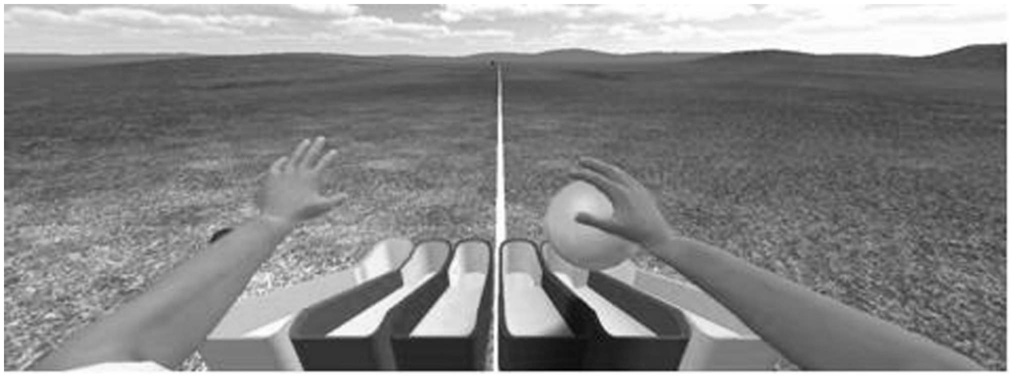
The use of games to enhance physical therapy and to motivate people's engagement towards rehabilitation procedures is increasingly gaining attention, partially due to the introduction of the low-cost Nintendo Wii platform. Hurkmans, Ribbers, Streur-Kranenburg, Stam, and Van den Berg-Emons (2011), examined whether embodied digital game play, such as Nintendo Wii Sports, could provide the required energy expenditure necessary for health improvement purposes. Ten chronic stroke patients participated in the study, who were instructed to play Wii Sports tennis and boxing for 15 minutes each. There was a 10 minute break between the games, which were played in a randomized order. Measures of oxygen uptake during exercise and rest were taken and physical activity was classified according to the American College of Sports Medicine guidelines and the American Heart Association guidelines. Results showed that, except for one patient in the tennis group, chronic stroke patients played Wii Sports tennis and boxing at moderate intensity, which is a sufficient energy expenditure for health maintenance and improvement purposes. In the following paragraphs we focus on evidence related to health related conditions of high prevalence in our society: stroke, cerebral palsy balance, and pain treatment.

Stroke and Post-Stroke Limb Rehabilitation

In a recent meta-analysis, Saposnik and Levin (2011) tried to determine the added benefit of VR technology on arm motor recovery after stroke. Thirty-five studies were identified, of which 12 met the inclusion/exclusion criteria totalling 195 participants. Among them, there were five randomized clinical trials and seven observational studies with a pre-/post-intervention design. An improvement of Fugl-Meyer, which is a measurement of motor impairment, was used as the primary outcome and the secondary outcomes included improvement in motor function measured by the Wolf Motor Function Test (WMFT), Box and Block Test, and the Jebson-Taylor Hand Function Test. Interventions were delivered within four to six weeks in nine of the studies and within two to three weeks in the remaining three. From the meta-analysis it appeared that there was a significant higher chance of improvement in motor strength for patients randomized to VR systems. Furthermore, there was a significant improvement in motor impairment and improvement in motor function outcomes from the observational studies. Eleven of the 12 studies showed a significant benefit toward VR for the selected outcomes and the authors conclude that VR and digital game applications are potentially useful technologies that can be combined with traditional rehabilitation for upper arm improvement post-stroke.

Colombo et al. (2007) designed two robot devices and used simple game elements-difficulty level of the task and feedback on performance-for the rehabilitation of upper limb movements of chronic stroke patients. In the study, a one degree of freedom (DoF) wrist manipulator and a 2 DoF elbow-shoulder manipulator were designed to be used for the treatment of the study participants, who suffered from chronic stroke. Visual feedback was provided on a TFT flat screen by three coloured circles. The participants had to follow a circular path for the wrist device and a square or a more complex path for the elbow-shoulder device. During the treatment, the device provided visual and auditory feedback to the patient and their task scores were displayed on the screen. By providing feedback on performance, the patients' interest remained high during the training session. In addition, precise measures were obtained of the patients, which provided the therapist with the possibility to present positive feedback for their efforts to enhance the patients' motivation and devotion to the training.

Figure 4. Image of the Spheroids game from the Rehabilitation Gaming System Project (© 2011, RGS Project Consortium; Used with permission)



Recently, the Rehabilitation Gaming System (RGS) project started on the use VR for post-stroke limb rehabilitation. An image of the RGS Spheroids game can be seen in Figure 4. The RGS can capture the movements of the arms by means of a camera that is positioned on the top of a display. The camera detects colour patches that are located on the elbows and wrists of the patient. Furthermore, a pair of data gloves (optic fibre) measure finger flexion. Da Silva, Bermudez, Badia, Duarte, and Verschure (2011) studied the clinical impact of the RGS VR system on time to recovery after acute stroke. Eight acute stroke patients used the system during 12 weeks in addition to conventional therapy and eight served as a control group who performed a time matched alternative treatment. After the therapy, between-group comparisons showed that the RGS group displayed significantly improved performance in the speed of the impaired arm, matched by better performance in the arm subpart of the Fugl-Meyer Assessment Test and the Chedoke Arm and Hand Activity Inventory. Furthermore, the RGS treatment group presented a significantly faster improvement over time for all clinical scales during the therapy. From the study, it appeared that rehabilitation with the RGS facilitates the functional recovery of the upper extremities. The authors suggest that rehabilitation gaming by means of the RGS is a promising tool for stroke neurorehabilitation.

Accordingly, Yong Joo et al. (2010) studied the feasibility of Nintendo Wii exercises in addition to traditional rehabilitation of patients with post-stroke upper limb weakness. In total, 16 participants - inpatients within three months after a stroke with upper limb weakness-received six training sessions over two weeks. The participants played Nintendo's Wii Sports, including boxing, bowling, tennis, golf, and baseball. All participants found Nintendo Wii gaming enjoyable and comparable to traditional training. There were small but statistically significant improvements in the Fugl-Meyer Assessment and Motricity Index scores; hence, Nintendo Wii appears to be a feasible device as an *addition* to conventional rehabilitation therapies for patients with post-stroke upper limb weakness. Mouawad, Doust, Max, and McNulty (2011) have also investigated the effectiveness of the Nintendo Wii in therapy for post-stroke rehabilitation. In their study, seven patients (post-stroke) and five healthy people who served as controls undertook one hour of therapy on 10 successive weekdays. From the study it was shown that functional motor ability improved for the post-stroke patients and a transfer of functional recovery to everyday activities of daily life was found.

Cerebral Palsy

A relevant improvement made in the combination of low-cost digital gaming and rehabilitation of cerebral palsy (i.e., motor impairments resulting from lesions of the brain) comes from the work of Deutsch, Borbely, Filler, Huhn, and Guarrera-Bowlby (2008). This team studied the feasibility and outcomes of using Wii Sports (boxing, tennis, bowling, and golf) to augment the rehabilitation of a patient with cerebral palsy. The patient performed 11 training sessions, of which two included other players. The sessions lasted between 60 to 90 minutes. Improvements in visual-perceptual processing ranged from a 4th percentile change in form constancy to a 70th percentile change in visual discrimination. Postural control improved in terms of greater loading on the lower extremities; other improvements were reported in centre-of-pressure sway decrease, more symmetry of medial-lateral weight distribution, and an increase in the ambulation with forearm crutches.

Qui et al. (2009) used the Haptic Master and rehabilitation simulations, to allow two children with hemiparetic cerebral palsy to interact with virtual environments. The participants performed a battery of clinical testing and kinematic measurements of reaching. A number of virtual simulations were used during the training, like a bubble explosion simulation and a car race. The car race presented the patient with a race track and three other competing cars. To accelerate or decelerate the car, patients had to either use a force forwards or backwards and the car could be turned by pronating or supinating their forearm. The participants completed nine hours of training in three weeks in which no negative responses to treatment were reported. One participant showed an overall performance improvement on the functional aspects of the testing battery and the other participant improved in the upper extremity active range of motion and in kinematic measures of reaching movements.

Another study on the rehabilitation of cerebral palsy was performed by Huber et al. (2010), who developed a pilot study which was designed to examine the feasibility of home rehabilitation by means of digital gaming to address hand impairments in patients with cerebral palsy. Three patients participated in the study and trained in their home environment for about 30 minutes a day, a couple of times a week, over a 6 to 10 month period. The participants wore a sensing glove and played custom-developed games on a modified Sony PlayStation 3, which were specifically designed for the purpose of accommodating the participants' limited range of motion and to enhance the finger range and motion speed. Three virtual reality finger exercises were applied of which one training the range of motion and two finger velocity exercises. Significant improvements were found in finger range of motion, which were related to self- and family-reported improvements in ADL. The authors encourage the development of new rehabilitation games, including games to train independent finger movement, endurance, power output, and force exertion. Again, although the results are promising, only a limited number of people participated in the aforementioned studies, and therefore future experimental research is needed with larger samples and controls to validate the potential of robotics and gaming in rehabilitation.

Balance

A widely used method for training balance by means of digital games comes from the use of Nintendo's Wii Fit with a balance board. The balance board has four pressure sensors under all four corners of the board, similar to a regular weight scale. The Wii Fit is a relatively new product marketed to improve-among others-balance and general fitness. Nitz, Kuys, Isles, and Fu (2010) examined the marketing claims of the Wii Fit in improving balance, strength, flexibility, and fitness for healthy people. Ten females participated in the study who were aged between 30 to 58 years. The training intervention involved a 30 minute session, twice a week for a total of 10 weeks. The participants were assessed before and after the intervention. Clinical measures for balance and mobility were collected, as somatosensory measures and cardiovascular measures. Results showed that balance and lower limb muscle strength improved significantly. Yet, changes in touch, vibration, proprioception, cardiovascular endurance, mobility, weight change, activity level, and well-being were not found. Hence, Wii Fit training was found to have an immediate effect on the strength and balance of the participants. Future studies, with more statistical power, should try to find additional support for these claims (Nitz et al., 2010).

In a related study, Graves et al. (2010) compared the physiological cost and enjoyment of exergaming on Nintendo's Wii Fit with aerobic exercise in three different age groups (adolescents, young adults, and older adults). In the study, cardiorespiratory and enjoyment measures were compared between the three age groups. The participants performed handheld (inactive) digital gaming, Wii Fit activities (e.g., yoga, balance, aerobics), and brisk treadmill walking (approx. 5 km/h) and jogging. For all groups, the energy expenditure and heart rate of Wii Fit activities were greater than handheld gaming but lower than the treadmill exercise. However, the heart rate during Wii aerobics fell below the recommended intensity for maintaining cardiorespiratory fitness. It is interesting to note that the group enjoyment was higher for the Wii Fit balance and aerobics activities than for the treadmill walking and jogging. As a conclusion, this study showed that Nintendo's Wii Fit is experienced as an enjoyable exergame for different age groups and that Wii Fit stimulates light to moderate intensity activity. It is apparent that the Wii Fit is an enjoyable platform for physical training, yet, its role as a valid rehabilitation tool requires further research. Lange, Flynn, Proffitt, Chang, and Rizzo (2010) also explored the use of digital game consoles such as the Nintendo Wii Fit as rehabilitation tools. According to the authors, case studies have demonstrated that the use of digital games may be beneficial for balance rehabilitation, yet, today's commercial off-the-shelf games lack compatibility with the specific training needs that are necessary to meet therapy goals. Therefore, Lange et al. (2010) developed a game to be played with the Nintendo Wii Fit balance board. The game design was based on focus group data and observations with patients that specifically targeted weight shift training. In the game, a player had to move a balloon to collect falling stars and to avoid falling rocks by changing the weight on the balance board in the direction they wanted the balloon to move. The usability of the prototype was evaluated by a number of clinicians and people with neurological injuries. The feedback was overall positive and the preliminary research provided support for the development of a rehabilitation game that targets the key requirements for training weight shift.

PAIN TREATED WITH VIRTUAL REALITY

The use of Virtual Reality (VR) games in pain treatment is based on a distraction of the thought processes in the brain, including pain experiences. Das, Grimmer, Sparnon, McRae, and Thomas (2005) examined the additional (positive) effect of playing a VR game combined with routine pharmacological pain treatment on procedural pain in children with acute burn injuries. The software that was used in the study was based on the game 'Quake' (ID software) and a head mounted display (HMD) with tracking system and mouse was used to interact with the virtual world. The simulation provided the children with the sense of being on a track on which they could use a pointer to aim and shoot monsters. The children had burns to more than 3 percent of their body surface area and required dressing changes. In the randomized trial, seven children acted as their own controls, in a series of 11 trials. The participants had to score their average pain experience using the Faces self-report pain scale at the end of each phase of a dressing change. The parents or carers and nurses were interviewed at the same time to gather their perceptions on the anxiety, pain perception, and the use of VR during the treatment. From the results it appeared that the average pain scores were lower when VR was combined with pharmacological treatment, than when medication was used alone. A subsequent randomized study by Rutter, Dahlquist, and Weiss (2009) examined whether the distraction of VR reduced cold pressor pain in adults. Twenty-eight adults participated and underwent one baseline cold pressor trial and one VR distraction trial in randomized order each week over 8 weeks in total. In the VR distraction trial, participants played the game 'Finding Nemo,' level 'Catch Dory' (Traveller's Tales), on the Sony Playstation 2 (PS2). The game world was viewed through a HMD with integrated headphones and controlled by a PS2 controller which was mounted to a table to allow participants to manipulate the controller with one hand while the other hand was in the cold pressor (i.e., water). The authors also found that VR distraction decreased pain, since the pain threshold and tolerance increased and pain intensity decreased. Both studies (Das et al., 2005; Rutter et al., 2009) provide support for the positive additional effect of VR distraction in pain treatment.

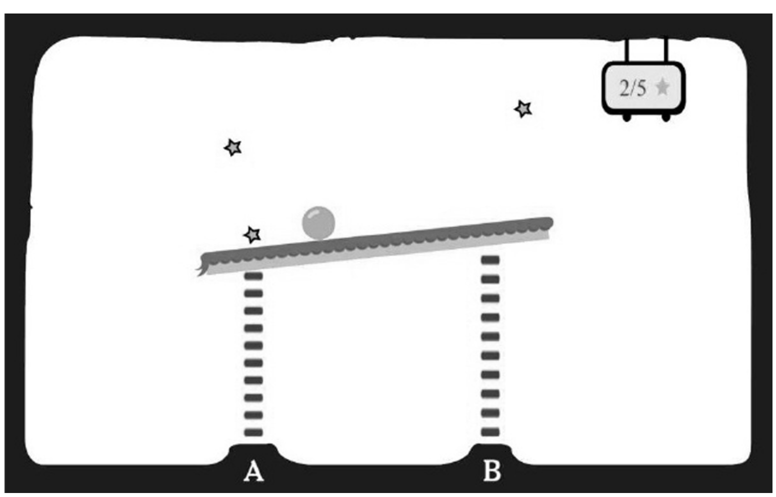
SOCIAL REHABILITATION GAMING AND GAMES FOR SOCIAL SKILLS AND PRO-SOCIAL BEHAVIOUR LEARNING

One of the main motivations to play digital games together is the possibility to interact with and meet others (Jansz & Martens, 2005; Staiano & Calvert, 2011). In respect to players' preferences, multiplayer and group game play is preferred over solitary play by preadolescent children (Chin A Paw, Jacobs, Vaessen, Titze, & van Mechelen, 2008) and older people have also been found to prefer co-located multiplayer gaming, however, not mediated over the Internet without the possibility for social interaction (Gajadhar, Nap, de Kort, & IJsselsteijn, 2010). From a number of experimental studies, it appeared that more enjoyment is experienced when playing against human co-players compared to a computer generated player (Gajadhar, de Kort, and IJsselsteijn, 2008; Gajadhar, de Kort, and IJsselsteijn, 2009). According to the authors, the possibility to communicate and interact with a co-player while playing adds to the fun and involvement experienced in digital game play (Gajadhar, de Kort, and IJsselsteijn, 2008; Gajadhar, de Kort, and IJsselsteijn, 2009). Social play is also receiving increasing attention in physical training (e.g., seniors with the Wii Fit; Aarhus, Grönvall, Larsen, & Wollsen, 2011) and in rehabilitation to reconnect patients in their social environments and to provide an additional incentive to engage in rehabilitation (Van den Hoogen, IJsselsteijn, & de Kort, 2009; Vanacken et al. 2010).

Vanacken et al. (2010) studied game-based arm rehabilitation and social play of multiple sclerosis (MS) patients. The value of force-feedback assisted rehabilitation of the upper extremities in MS patients was examined. Furthermore, it was studied how such technologies (i.e., a VR Environment) can be applied in a self-motivating way, providing the patients with training tasks to be carried out and monitoring their progress and success rate. The added value is the inclusion of a collaborative rehabilitation environment, opening up the possibility of social play. One of the co-play games is the BalancePump game; a two player game in which the goal is to collect all stars by hitting them with a ball, which can be seen in Figure 5. The ball can be moved by lifting the ends of the beam and each end is controlled by one of the players involved in the game. A player performs a pumping gesture to move his/her end upwards as such that the ball can roll towards a star. The relative or friend that participates as a co-player in the game uses a Wiimote, while the patient uses the Haptic Master (a 6 degrees of freedom force controlled robot) with gimbal. The authors demonstrated how collaboration between a patient and relative can be used for social play in rehabilitation gaming. According to the authors, social rehabilitation, in particular with relatives, friends, or other patients could potentially enhance the motivation for training (Vanacken et al., 2010). We foresee future experimental research in which the relation between the presence of a co-player and the effectiveness, motivation, and enjoyment in rehabilitation is studied.

Aside from studies on the enjoyment and motivational factors of social play, Durkin and Barber (2002) studied the relation between digital game play and social behaviour. Adolescents who played digital games scored more favourably than non-players on several measures such as family closeness, activity involvement, friendship network, and (less) disobedience to parents. Furthermore, Greitemeyer and Osswald (2009) examined if playing pro-social digital games reduces aggressive cognitions, and found that playing a prosocial digital game reduced the hostile expectation bias and decreased the accessibility of antisocial thoughts compared to playing a neutral game. However, these benefits cannot be attributable only to non-violent digital games. Ferguson (2010) states that the so called Massively Multiplayer Online Role Playing Games (MMORPGs) such as World of Warcraft (Blizzard Entertainment) allow for complex social interactions to occur within the game world, and that those social connections can be very meaningful to those involved. In relation to this, Ferguson and Rueda (2010) examined the causal effects of digital game playing on aggressive behaviour, hostile feelings, and depression, with 103 young adults. The participants were provided with a frustration task and then they were randomized to play a nonviolent game, a violent game with a good versus evil theme (i.e., playing the bad or the good guy), or they played no game. The authors found no evidence that short-term exposure to violent video games either increased or decreased aggressive behaviour. Yet, a history of real-life violent video game-playing was predictive of decreased hostile feelings and decreased depres-

Figure 5. Collaborative BalanceBump training task (© 2011, Hasselt University - Expertise centre for Digital Media; Used with permission)



sion. It is suggested that violent games could, at least for some individuals, reduce depression and hostile feelings in players through mood management.

REHABILITATION GAMING: FUTURE TECHNOLOGIES

For decades, doctors and therapists have explored and used a variety of technologies to enhance the rehabilitation process, and in the previous literature review, a number of systems have already been introduced, like Nintendo's Wii with balance board, the Rehabilitation Gaming System, and robot devices like the Haptic Master. With the introduction of low-cost 3D motion sensing, like Microsoft's' Kinect and Sony's Playstation Move, new possibilities arise for rehabilitation training. In the following sections, we will shortly discuss some of the systems and future technologies that have received little attention in the previous sections and discuss some studies that support the use of these systems for rehabilitation purposes.

3D Motion Sensing

One of the latest advancements in rehabilitation gaming is the commercially available SilverFit platform that operates via 3D motion sensors. SilverFit provides a hardware and software platform to facilitate physical rehabilitation after e.g., a stroke, a fall, or a cardiac incident. The solution uses a time-of-flight (TOF) camera that can monitor the body movement of a player in three dimensions. TOF monitors the distance to a 3D object by measuring the absolute time a light pulse needs to travel from a source into the 3D scene and back after reflection. TOF is different from the infrared 'LightCoding' technique used by Microsoft Kinect, which projects a light pattern into a 3D scene, which is viewed after reflection by camera(s). A distortion of the light pattern on the object allows for computing the 3D structure (Castaneda & Navab, 2011).

The SilverFit system can trace body posture adjustments, arm movements, standing up, sitting down, walking, etc. within a 5x5 meter area. The input is converted into game elements shown on a High Definition (HD) flat screen or via beamer (Rademaker, Van der Linden, & Wiersinga, 2009). Figure 6 shows a rehabilitation session with the SilverFit system. The patient was recovering from a hip surgery, who was afraid to walk with a stick without support. During the session, she picked flowers in the rehabilitation game, with increasing speed in all directions. Afterwards, the patient acknowledged that she was not consciously aware about her walking, because "she had to pick flowers" (Pieter van Foreest, 2011). The state of the patient during the session is similar to a 'flow' state described earlier in this chapter, and the example shows the strength of rehabilitation gaming, because the patient performed movements she was afraid of and would otherwise not perform.

Another, yet more expensive, 3D motion system that is used in rehabilitation is CAREN (Computer Assisted Rehabilitation Environment) for the medical treatment of military and civilian patients. The CAREN system allows a patient to stand on a computer driven motion platform surrounded by multiple projections of a VR world. A number of cameras track the patient's position via markers that are placed on his/her body. CAREN offers a test environment with means of almost unlimited exploratory behaviours for patients and a strong tool for motor control research (van der Eerden, Otten, May, & Even-Zohar, 1999).

Brain-Computer Interfaces

Research on Brain-Computer Interfaces (BCIs) started in the 1970s and has recently seen an increasing interest in rehabilitation and digital gaming. BCIs can use a variety of information

Figure 6. Rehabilitation by means of the SilverFit at Zorginstellingen Pieter van Foreest, Physiotherapy 'De Naaldhorst', Netherlands (© 2011, Pieter van Foreest; Used with permission)

types from the user's brain activity to execute actions and tasks. For example, sensory perception, motor control, imaginations, stress levels, and workload can be translated into computer actions (Krepki, Curio, Blankertz, & Müller, 2007). Most BCIs use an Electroencephalography (EEG) in real-time for the interaction with a computer, which can be seen in Figure 7. To control a game by means of brain activity, for example to walk forward, a player may be instructed to think about moving his legs. The EEG data that is associated with this thought will be correlated with walking forward. According to Nijholt, Plass-Oude Bos, and Reuderink (2009) any computer action could in potential be controlled by certain brain activity, although an appropriate mapping is feasible, e.g., it is more convincing to mentally move your legs for a virtual walk than performing a mental rotation task for walking.

A BCI application that has currently great potential involves rehabilitation to regain motor control lost from diseases such as a stroke (Moore Jackson & Mappus, 2010). A case study of Broetz et al. (2010) showed that a combination of BCI training with goal-directed, active physical therapy may improve the motor abilities of chronic stroke patients. The patient in his/her study could not extend his fingers, hand, or arm for any relevant activity of daily life. During the training, brain activity was identified by means of an EEG and a magnetoencephalogram (MEG) to drive an orthopaedic apparatus (orthosis) and a robot attached to the patient's affected upper extremity, and the robot enabled him to move the paralyzed arm back and forward by depending on the μ-rhythm modulation. The μ-rhythm activity is generally related to an inactivation of the motor system. After one year of training, the ability of hand and arm movements as well as speed and safety of gait improved significantly. A positive relation was found between increased ipsilesional μ-power and the motor improvement. The authors suggest that a rehabilitation intervention by BCI could support chronic stroke patients who lack residual finger extension (Broetz et al., 2010), yet, there is still limited evidence for the effects.

Rehabilitation Gaming Integrated in Smart Homes: Future Prospects

Aside from the potential of new technologies in rehabilitation gaming, we foresee a future in which these types of systems are integrated in smart living; as such that rehabilitation can take place at home. This is particularly valuable because the population is aging: in 2050, more than a third of the European population will be aged over 60 years (UN, 2008), and it is likely that the workforce will not be able to support the people who are retired, in pensions and healthcare. These future prospects demand for solutions that require fewer costs with less people. In potential, telemedicine and eHealth solutions, integrated in a smart home, could reduce the workforce costs. Furthermore, these solutions can provide health care professionals the possibility to interact (e.g., via Vo-IP) and provide medical care to people who live in remote rural areas and who may have

Figure 7. A player controlling the World of Warcraft game, using brain activity and the mouse and keyboard (© 2011, Anton Nijholt; Used with permission)

difficulty travelling to care providers, in particular specialized care.

Game-based telerehabilitation (Lange, Flynn, & Rizzo, 2009) and in-home rehabilitation gaming (Huber et al., 2010) have received wide spread attention and are increasingly applied in addition to regular telemedicine and rehabilitation solutions. However, a largely unexplored area for rehabilitation gaming is the *integration* in smart living. The infrastructure of a smart home can use and integrate any information derived from sensors, actuators, and interpreters to support independent living. The information that can be derived from a rehabilitation game, e.g., motor improvements and in-game scores, can be sent in real-time to care professionals who can monitor and react to deviations. Within the smart home, persuasive agents or avatars displayed on a television or mobile phone could prompt and motivate users to train whenever they should. Furthermore, movement and presence sensors that detect low activity could also be used to remind the user to exercise or just to perform a desired level of activity. For optimal rehabilitation, it is crucial that a patient is well nourished and a smart home can support patients to prevent malnourishment. Half of all stroke patients are malnourished on admission to the inpatient rehabilitation service (Finestone & Greene-Finestone, 1999) and the factors that are associated with malnutrition include poorer functional outcome and prolonged rehabilitation stay. Different types of sensors in the kitchen can track the intake of food and drinks and could prevent malnutrition by reports to the care providers who can act accordingly, but also to (in-game) persuasive agents who remind the patient to drink and eat when necessary. Telemedicine devices like an online blood pressure monitor and weight scale can also provide an indication of malnutrition. In a study of Parker et al. (2009) it was found that rehabilitation at home showed no disadvantage compared to day hospital rehabilitation. Although it was found that home-based rehabilitation was not cheaper than day hospital rehabilitation, it is expected that the prices will change with time. The market of eHealth and telemedicine products is relatively new and is still serving a niche market. Insurance companies are more and more willing to contribute to the costs of these products and services, and therefore it is expected that these products and services will become cheaper in the future ahead. Future studies could focus on reducing the costs in rehabilitation gaming while maintaining high quality care. Furthermore, future research is necessary to explore the possibilities of integrating game elements in the home rehabilitation process, as an incentive to train and to enhance the enjoyment during rehabilitation. In addition, social rehabilitation with family and friends could enhance the effects even further.

CONCLUSION

Rehabilitation games make use of the motivating features of entertainment games that trigger the playful mind and induce challenge, fantasy, control, cooperation, and competition. As shown by the numerous studies reported in this chapter, the entertainment value and feedback mechanisms of games enhance the motivation to engage in rehabilitation, and some studies even show an advancement compared to conventional rehabilitation methods. Furthermore, with the rise of low-cost rehabilitation devices we expect that rehabilitation gaming could in potential reduce the increasing costs in health care, especially when the treatment can be performed in the home environment. A small number of rehabilitation games and systems have found their way to market, yet, the challenge of commercialization remains. For the future, it will be important that people in health gaming research, business, and government closely work together to find ways for funding and commercialization possibilities. Furthermore, sufficient effort should be spent to ensure that rehabilitation games and technologies meet the health and social needs of all people. Although there is an increasing body of evidence for the benefits of rehabilitation gaming, there is a constant need for further exploration and validation. According to Lieberman et al. (2011) there are a number of gaps in research on the efficacy of exergames for rehabilitation, for example there is a need for studies with randomized controlled methods to identify how digital game play influences behaviour. Furthermore, there is still limited evidence for an actual transfer of the activities trained during digital game play to ADL. In respect to the game design and the apparatus for rehabilitation gaming, we should take age related preferences and abilities into account since a number of studies showed that older people have specific gaming needs and differ in their abilities from young adults (De Schutter, 2011; IJsselsteijn, Nap, de Kort, & Poels, 2007; Nap, de Kort, & IJsselsteijn, 2009; Pearce, 2008). Qui et al. (2009) also reported about age specific preferences. The rehabilitation games that were used in their study were specifically designed for the rehabilitation of adults and a number of these games did not resonate well with children (Qui et al., 2009). Future studies in rehabilitation gaming should rather take age specific needs and abilities into account, to increase the positive return from rehabilitation gaming even more. Adaptive and personalized games could potentially overcome the obstacles to successful and rewarding game play. A challenge that needs further exploration in rehabilitation gaming, particularly at home, is to ensure the safety and health during training.

Despite the research gaps, we became inspired by the increasing work on rehabilitation gaming and the potential these games have to train motoric, cognitive, and social abilities. For the future, we see room for social rehabilitation gaming, the integration of rehabilitation games in smart living, new embodied gaming technologies, and gamification of real-life activities that could enhance the rehabilitation process even further.

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KEY TERMS AND DEFINITIONS

BCIs: Brain Computer Interfaces, which can use a variety of information types from the user's brain activity to execute actions and tasks.

Exergames: Games that are developed for the purpose of physical training.

HMD: Head Mounted Display, a binocular or monocular display that is worn on the head or integrated in a helmet and can track the position and angle of the head.

Rehabilitation Gaming: The use of digital games for motoric, cognitive, and social rehabilitation and recovery.

Self-Efficacy: Personal expectations about the ability to succeed in specific situations.

Serious Games: Games that are developed for the purpose of training, learning, and skill acquisition.

Virtual Reality: An interactive simulated environment that can induce physical presence and can be accessed by means of a head mounted display and data gloves.