Using social gaming to improve stroke patients motivation and engagement in rehabilitation therapy

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Using social gaming to improve stroke patients motivation and engagement in rehabilitation therapy

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ABSTRACT

Cardiovascular accidents (CVAs or strokes) are one of the major causes of disability and death worldwide. One of the common problems that surviving CVA patients have is the inability to coordinate or move one or more limbs, usually on one side of their body, contralateral to the affected brain areas. Rehabilitation from this kind of brain injury is an effortful, time-intensive and at times exasperating process. While some stroke survivors recover quickly, most stroke survivors need some form of long term stroke rehabilitation, possibly for months or years after their stroke. Often patients find it difficult to cope with their new condition, and depression is a common condition during as well as after treatment.

Our research explores new ways to help motivate patients who suffered from a stroke throughout the recovery process, and make rehabilitation more enjoyable by offering a game-like experience. The main aim of the project is to investigate the potential of social gaming in the context of stroke patients’ rehabilitation process and their effect on engagement and motivation in persisting with the necessary exercise regime. In consequence, having a higher degree of engagement in the required exercises is likely to lead to better outcomes of the therapy process.

In order to address our research question, a social game that can be used in upper-limb recovery by stroke patients has been developed. The application is an extension to the CONTRAST game prototype presented in Jacobs, Timmermans, Michielsen, Plaetse, & Markopoulos (2013) and follows principles of rehabilitation game design. A total of 15 participants from current recovering patients of Jessa Ziekenhuis (Hospital) in Herk-de-Stad, Belgium, took part in the experiment and were asked to play the game. Two experimental conditions were considered – virtual co-play and co-located co-play. The design was manipulated so that participants are made to believe that they are playing the computer, while in reality it is still a human opponent. This method is called Wizard of Oz. As a manipulation check, social presence was evaluated for both cases. Also their gaming experience were extracted using specialized questionnaires.

The results show the manipulation was somewhat successful, yielding marginally significant differences in social presence between conditions. The main findings highlight a significant difference in Tension between the two conditions, participants reporting to be less tense in the multiplayer condition than the single player one. Other results show that in the multiplayer condition participants were more Challenged and felt less Competent and experienced less Flow compared to the single player condition, although difference were only marginally significant. There were no differences in experienced feeling of Negative or Positive Affect and Immersion between the two conditions.

Although the evidence presented in this research is not conclusive, there is great potential for integrating social games in rehabilitation therapy. Follow-up studies might offer better insights on how social gaming can be optimized to help motivate patients to carry on the rehabilitation with greater optimism and success.
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In her recent book, “Reality Is Broken: Why Games Make Us Better and How They Can Change the World” (McGonigal, 2011), game designer and author Jane McGonigal describes, in one of the chapters, her experiences after suffering a traumatic brain injury. The major headaches, vertigo and agnosia that followed prevented her to work, think and properly interact with those around her. Although recovery was a slow process she was assured by her physician that the recovery would take no more than a month, provided that she gave up all her daily activities like reading, writing, computer games, caffeine and so on. After the month has passed and no progress was visible, negative emotional states like depression and even suicidal thoughts began to take over her mental state. These negative feelings had a clear detrimental effect on her recovery, slowing the process altogether. In a moment of desperation, she said to herself: “Either I’m going to kill myself or I’m going to turn this into a game.” Based on her belief that games, in general, provoke positive emotions, she decided that this could help in her recovery process. And thus she “developed” a self-gamification project called SuperBetter to help heal her own brain injury. The game was mostly a thought exercise and it was based on an adventure where your main goal is to (re) power up your abilities. It included a series of game elements like quests (in form of to do lists), enemies (your disabilities), allies (friends and family who will track your progress) and heroes (yourself). SuperBetter is not only about 'getting better', but also to offer motivation for people to do things they would like to do even though they might not be feeling able. In the end, the “hero” will feel better with who they are at that moment. Jane McGonigal writes that the goal of the game is not to replace traditional rehabilitation methods, but to augment them and help patients take a more active role in their recovery. She also writes that it is more likely for players to stay positive in this alternate reality, where friends and family can work together with patients towards reaching their goal (partial or full recovery). The game recently became commercially available, helping users overcome a series of personal challenges, from losing weight to running a marathon. The game helped Jane completely recover from her brain injury.
This short story served as an inspiration for the current thesis. The research reported here explores new ways to help motivate patients who suffered from a cardiovascular accident (CVA or stroke) throughout the recovery process, and make rehabilitation more enjoyable by offering a game-like experience. Stroke rehabilitation can be a long and trying process for both patient and therapist. For discharged patients, the stages of unsupervised training are usually difficult to sustain and follow, especially when the patient experiences depression after treatment. This research investigates whether social gaming can augment motivation to engage in the training regime that is necessary for recovery. The approach engages social support from friends and family in the rehabilitation process, offering patients new opportunities to improve social interaction and reintegration during their rehabilitation, and consequently enable a shift towards home-based therapy.

1. Stroke rehabilitation

Cardiovascular accidents are a major cause of disability and death worldwide. Most of the time, they have devastating and life-altering effects on survivors. According to official statistics of the American Stroke Association strokes kills around 140,000 people each year, making it the 4th cause of death in the US (Towfighi & Saver, 2011). In today’s aging society, stroke prevalence is becoming more likely since 95% of strokes occur in people age 45 and older, and two-thirds of strokes occur in those over the age of 65 (Senelick & Dougherty, 2001).

CVAs are generally caused by disturbances or interruption of blood flow to the brain and result in severe loss of brain functioning (for general reference, see: Wade, Hewer, Skilbeck, & David (1985)). The specific disability caused by a stroke depends on the extent of the damage and part of the brain where it occurred. Stroke in the right hemisphere can lead to partial or full paralysis in the left side of the body and usually decreases spatial and perceptual abilities such as reaching and handling objects and undertaking routine habits such as dressing. Conversely, a stroke occurring in the left hemisphere can lead to partial or full paralysis in the right side of the body and usually decreases cognitive abilities such as speaking and comprehending language (aphasia). In both cases short-term memory might be affected, making it more difficult for patients to acquire new information and maintain it. Strokes occurring in the cerebellum usually lead
to predicaments in body posture and balance. One of the common problems that surviving CVA patients have is the inability to coordinate or move one or more limbs, usually on one side of their body, contralateral to the affected brain areas.

Rehabilitation from this kind of brain injury is an effortful, time-intensive and at times exasperating process (van der Lee, Snels, Beckerman, Lankhorst, Wagenaar, & Bouter (2001)). After a stroke, even the most basic of movements can become impaired. In order to move one part of the body, the brain sends a message to corresponding muscles or muscle groups through neural pathways. Because of damage, the brain has more difficulty operating these neural pathways, which results in difficulty of movement, stiffening of muscles (spasticity) or paralysis. In order to regain basic motor functions, patients usually work together with a physiotherapist on a daily basis. The main goal of the first stages of the rehabilitation is to make the patient as independent as possible, by restoring their walking ability, range of movements and balance. Another important step in rehabilitation is occupational therapy, which involves relearning and regaining skills necessary in everyday life activities such as eating, dressing and personal hygiene. A good portion of the rehabilitation process is targeted to regaining control and fluency in Activities of Daily Living, or ADLs, as they are critically important to a patient’s both physical and mental recovery.

2. Psychological difficulties and social support

While some stroke survivors recover quickly, most still need some form of long-term rehabilitation, possibly for months or, in more severe cases, years after their stroke. Often patients find it difficult to cope with their new condition, and depression is a common condition, both during as well as after treatment (Aström, Adolfsson, & Asplund, 1993). The main psychological challenge recovering patients have to face is adjusting “existing assumptions about the identity self-concept and role capacity” (Glass & Maddox, 1992, p. 1250). Sociologically, such events result in shifts in social roles and identities, altering individuals’ capacity for proper functioning in their social roles as parent, partner, employee, and so on. Despite the fact that most stroke survivors eventually return to their homes and communities, most of them still struggle to reestablish functional independence and to accept their new self-identity (Brookehurst, Morris, Andrews, Richards, & Laycock, 1981). It is often the case that patients adopt
self-preservation behaviors in order to reestablish continuity between their pre-stroke identity and post-stroke reality, which might affect interactions and human relations with those around them.

High levels of social support are often associated with faster and more extensive recovery (Glass, Matchar, Belyea, & Feussner, 1993). The amount of support provided needs to be balanced; too much attention might be perceived as overprotection and might lead to unwanted assistance. Social networks around patients often face difficulties in (re)connecting with the patients. Partners that care for them during recovery run an increased risk of becoming depressed themselves, which becomes more likely when the patient is depressed or shows a low level of general activity (Wade, Legh-Smith, & Hewer, 1986). Thus, besides focusing on regaining physical abilities, during the recovery process one should also pay attention to the mental health and wellbeing of both the patient and their caregiver (esp. their partner), as well as to the significant social adjustments that are required.

3. Potential of games as stroke recovery tools

In order to bring about significant recovery, stroke patients must perform a substantial number of daily exercises at home after they are discharged. These are usually highly repetitive, and the practice tends to become tedious. Due to this, a recent study indicates that although therapists prescribe home exercises and routines for most patients, only 31% of them actually perform these as recommended (Shaughnessy, Resnick, & Macko, 2006). Another shortcoming to home rehabilitation is the lack of performance feedback and achievement psychological incentives. With the increasing number of cases that need permanent supervision from a physiotherapist, a human resource problem also arises. As a consequence, patients might not reach their full recovery potential.

Studies have investigated the use of more complex technology to aid both therapists and patients in their tasks and offer a viable alternative or complement to classical therapy. Some examples include robotics (Johnson, Loureiro, & Harwin, 2008; Vanacken, et al. (2010)) virtual reality (Weiss, Kizony, Feintuch, & Katz, 2006; Crosbie, Lennon, McGoldrick, McNeill, Burke, & McDonough, 2008), augmented reality (Burke, McNeill, Charles, Morrow, Crosbie, & McDonough, 2010) and tele-rehabilitation.
In recent years, most of these technologies have become widely available and affordable. In most cases, these advanced tools are complementary to regular therapy rather than a replacement of therapists. All the clinical decisions regarding the application’s functioning are still made by the therapist. These kinds of systems are not yet likely to incorporate all the skills of a trained therapist, but with proper instructions and clear goals may be able to assist and even autonomously conduct simple repetitive and manually intensive therapy tasks.

One line of research that has shown promising results is integrating computer games in the rehabilitation process (Nap & Diaz-Orueta, 2013). The use of so-called “serious games” brings numerous benefits, such as increasing engagement and motivation in the rehabilitation tasks (Betker, Szturm, Nett, Naaz, & Kapadia, 2007), which in consequence leads to better outcomes in the therapy and contributes to cognitive, psychological, motoric, and social rehabilitation. The artificial environments created in these games have the potential to deliver safe and customizable training specifically tailored to the patient’s disabilities and stage of recovery.

4. State-of-the-art gaming for rehabilitation

Several game-like systems for both motor and cognitive recovery have been reported in recent literature (for reviews see: Nap & Diaz-Orueta (2013), Rego, Moreira, & Reis (2010), Gamberini, Barresi, Majer, & Scarpetta (2008)), making it an active research area. Most research on use of rehabilitation games in stroke recovery therapy practices focus mainly on “single player” implementations, where the social factors are, at most, secondary. Also, due to the fact that access to target population over long periods of time is problematic, evaluations are generally done through questionnaires investigating patients’ experiences and game performance measurements over a limited number of trials. Due to assistance needed by patients to operate the systems, is often the case that prototypes are evaluated in clinical settings rather than home environments. Computer-based motor rehabilitation systems are usually centered on a functional activity, such as grasping and moving an object, making a meal, etc. For example, Delbressine, et al., (2012) used a system that combines tangible tabletop interaction with wearable technology to assist stroke patients in exercising their arm-hand skills in a task-oriented
manner. The game developed for this system focused on practicing eating with cutlery, while trying to catch a virtual insect that appears on the screen. The system uses an interactive and dynamic computer-generated interface. Patients are given vibrotactile feedback regarding posture through a motion-sensing jacket. By making use of ADLs, patients report the playful approach as a credible addition to their rehabilitation, although they had reserved appreciations about sustained long term benefits. Another commonly used technology is motion trackers through webcams. These types of Augmented Reality rehabilitation games are usually aimed at exercising ample hand movements. Burke, McNeill, Charles, Morrow, Crosbie, & McDonough (2009) have developed two such games (Rabbit Chase and Arrow Attack) for single arm and bimanual rehabilitation. Tracing hand movements in two dimensions is made using a marker the patient holds (e.g. a glove). The game also features adaptable difficulty according to player’s performance as well as visual feedback information on the current progress. Game usability and playability were preliminary evaluated with healthy players, and subsequently with a few stroke patients that generally reported the game to be challenging, fun and varied. Due to system design, the game can easily be used in home environments as well, although special supervision might still be necessary.

Only a reduced number of studies have included social elements in the game prototypes (e.g. the possibility to play a game with others - multiplayer). For this purpose, some researches have investigated the use of commercial video game software and console platforms for upper-limb rehabilitation. Game consoles are relatively cheap alternative compared to the specialist VR or robotics equipment and allow for rich social interaction due to their co-located multiplayer game capabilities. Loureiro, Valentine, Lamperd, Collin, & Harwin (2010) selected the Wii Sport game pack to investigate user acceptance and usability of Nintendo Wii gaming console as a low cost treatment alternative to complement current rehabilitation programs. Both single and multiplayer versions of the games were trialed, with rather relaxed games such as bowling being preferred by patients to more pacy ones, such as air-hockey. Although judgments about including Wii games as part of the therapy were generally positive (89% of participants considering it should be a regular part of their therapy), the results of the study also yield that participants had difficulties with both the hardware (holding on to the Wii remote) and software (games not well paced for their condition. Thus it can be concluded that specialized games with a high degree of customization could offer better results in therapy rather than of the shelf commercial games. One example of such a game used for
upper limb rehabilitation is a two-player game presented in (Vanacken, et al., 2010). The two players have to collaborate in a balancing task, by collecting falling stars with a ball that rolls on a beam. The two players control each end of the beam. There are two input methods: Wii remote or force-feedback device. Thus the game can be played by two patients or by a patient and a healthy person (ideally a friend or relative). The game setting encourages social interaction, and networking capabilities (playing the game remotely) facilitates participation from family members and friends that cannot make it to rehabilitation center. Another study that elaborates on using social gaming for rehabilitation is Ballester, Badia, & Verschure (2011). The research explicitly investigates the effect of social interaction in stroke rehabilitation, using a Virtual Reality System suited for upper extremities motor rehabilitation. Patients participated in a memory card game, playing in a single player mode during one session and in a multiplayer mode during another session. Measurements of reaching movement of arms during the tasks were significantly higher in multiplayer sessions than in single player ones. The authors also report differences in enjoyment patients experienced between the two conditions.

As can be seen, research on the explicit effect of social elements (interaction, presence etc.) in rehabilitation games is still in incipient phase, but the prospect shows promising potential.

5. Game design principles for rehabilitation

Many of the games for rehabilitation presented in literature are made of tasks, which although are game-like, they usually don’t adhere to mainstream game design principles and patterns, but rather just borrow from them (Burke et al. 2009). In order to establish the requirements for these games, programmers often work together with therapists and stroke survivors. In many cases, they undertake multiple design iterations, in order to fully understand the needs and expectations of both therapists and patients. One of the biggest qualities of these games is that it engages a patient to the point where they no longer focus on the fact they are in a rehabilitation session (Rizzo & Kim , 2005). Rather than being highly immersive, rehabilitation games focus on sustaining self-motivation and improving engagement in the tasks. These factors may increase adherence to rehabilitation therapy program.
Salen & Zimmerman suggest that the goal of successful game design is the creation of meaningful play (Salen & Zimmerman, 2003). This emerges from the relationship between players’ actions and the system outcome. The interaction relationship should be made clear and the player should perceive how his choices are affecting the game (both in the short and longer run). Game mechanisms allow a wide variety of feedback, from numerical and textual, to haptic or audio. Without a quantifiable advantage for successfully doing a task and exposing disadvantages for poor gameplay, the player is less likely to engage with the game (Koster, 2005). This is also very important for controlling how patients cope with both success and failure through the game. Because the goal is to encourage engagement and reward it with success, failure is often less of a dramatic event in rehabilitation games, as opposed to commercial games. By handling failure in a positive way players are more likely to remain engaged and not feel that failure in the game is a direct consequence of their condition.

Csikszentmihalyi’s theory of Flow (Csikszentmihalyi & Csikszentmihalyi, 1988) suggests that challenge in a game should be presented at a steady rate, without making it too low and cause boredom or increasing it beyond player ability and cause frustration. Task difficulty can be adjusted in accordance with a patient’s progress and ability, so as to continue to challenge the patient at a level that is neither too difficult nor too trivial. Due to the repetitive nature of physical rehabilitation, this can help maintain patient enjoyment and therefore increase patient motivation. Rehabilitation must be targeted to the individual needs of the person with stroke and thus therapists should be able to set a starting difficulty level according to each patient’s physical condition and progress in therapy. The game should be designed so as to adjust its level of difficulty once players accomplish tasks with more ease or more difficulty. This means that the player’s cognitive and motor skills systematically exceed or are surpassed by the challenge level of the game.

Ryan & Deci (2000) introduced the Self-Determination Theory (SDT) to study self-motivation in social settings. SDT is a general theory of motivation, which has been applied to gaming as well (Ryan, Rigby, & Przybylski, 2006), as games are clearly examples of artifacts that exert a significant motivational pull. Patients that participate in rehabilitation therapy are already extrinsically motivated, since completion of the tasks (although they might sometimes be repetitive and tedious) has clear benefits: improvement to their condition. However, extrinsic motivation may sometimes be hard to maintain. Games have the ability to intrinsically motivate people, meaning that they
will perform the activities for their own sake (e.g. for fun) and not for their outcome. According to SDT, this type of self-motivated behavior is easier to sustain on the long term. Self-motivated behavior is driven by three needs: autonomy, competence and relatedness. Including exercises of daily activities of their choice into the game task design can further enhance the perceived autonomy of patients. Proper feedback can also assure the patient of his level of competence and inform them how their condition is improving. Also, sharing the experience with others contributes to rebuilding social connectedness by facilitating participation and interaction for family members or other patients. In the current study we are focusing predominantly on relatedness, and how this motivational dimension influences patients’ experiences in the context of a rehabilitation game.

6. Social gaming for rehabilitation

One of the most important additions to the classical paradigm in gaming in the last decades is the enhancement of the social experience. The main reason players engage in social gaming is the possibility to interact with other players (Clarke & Duimering, 2006). While digital games offer the possibility for many meaningful social interactions (de Kort & IJsselsteijn, 2008), this could also prove essential for engaging patients in rehabilitation games. There are many layouts for social gaming, varying according to player co-location (in the same physical space or mediated) and player roles (collaboration or competition). In the case of rehabilitation games, the scenario that might offer most opportunity for social interaction is co-located co-play (playing together with a player in the same physical space). By engaging in social interaction, several feelings may develop between the players, such as intimacy, closeness and understanding. This might prove even more beneficial if those that play together with the patient are family members or close friends. During play these feelings might be enhanced by the situations that the players are put through. Strengthening the response with a social incentive (such as facial expression or vocalization) and rewarding a performance will make players feel good about themselves and more optimistic about their performance and the therapy.

Presence of others might have other consequences on the experience of players. The mere presence of others might make players perform better on simple or well-learned tasks, a phenomenon known as social facilitation (Zajone, 1968), but may lead to worse
performance on more complicated or novel tasks. This latter effect is known as social inhibition. Fear of negative evaluation from our peers is the main reason for this. Due to great variability in patient population, in terms of social abilities (in case patients are playing against each other) or clear physical advantages of healthy players (when patients would play non-patient opponents) competition type games might not be suitable for rehabilitation games, since poor performance compared to the others might engender or deepen the idea of incompetence a patient may already be experiencing throughout his recovery period.

By stimulating collaboration with other players, patients could be encouraged to start and continue to engage in the necessary exercises (Vanacken, et al., 2010). Implementing asymmetrical levels of difficulty could also ensure that the game is challenging and engaging for the healthy and more physically able players as well (van den Hoogen, IJsselsteijn, & de Kort, 2009). This must be done so that the difference in difficulty is not made obvious, otherwise this strategy might backfire. Difficulty must be introduced in the least obvious and visible parts of the tasks (such as input methods or scoring mechanisms).

7. Rationale of this study

As presented earlier in this section, the introduction of games in rehabilitation therapy is beneficial for numerous practical reasons. Most importantly this new approach is not (yet) able to produce a shift from classical therapy, but rather augment it and fill in the gaps. Although there is great openness for this novel method of therapy adherence and acceptance from patients and therapists is still marginal, mostly due to lack of strong evidence of its efficiency compared to regular recovery therapy.

While the current state-of-the-art research covers a broad range of technologies for their use in rehabilitation therapy, a large part of it focuses on “single player” implementations. This thesis is an exploration ground that has not yet been exploited to its full potential. The research question is:

*Can social gaming elements included in rehabilitation exercises improve stroke patient's engagement and motivation in carrying out the therapy tasks?*
The main aim of the project is to investigate the potential of social gaming in the context of stroke patients’ rehabilitation process and their effect on engagement and motivation in persisting with the necessary exercise regime. In consequence, having a higher degree of engagement in the required exercises is likely to lead to better outcomes of the therapy process.

In order to address our research question, a social game that can be used in upper-limb recovery by stroke patients has been developed. The application is an extension to the CONTRAST game prototype presented in Jacobs, Timmermans, Michielsen, Plaetse, & Markopoulos (2013) and follows the principles highlighted in this introduction section.

In order to maximize its social potential, the ideal scenario for the game is to be played by a patient and someone close to him (family or friends) and preferably in their homes. The next section introduces the game and details the design principles used.
THE SOCIAL CONTRAST GAME

Following the first stage of the project that was made up of multiple design iterations based on feedback from both therapists and patients, the main principles followed by the game design are:

- The game input for the first player takes the form of a regular day activity (moving a cup, lifting a bottle) thus making it a meaningful activity.

- Visual complexity is kept at a minimum in order to not cognitively overburden the patients. Also game mechanics are kept at the simplest level possible while not making the game too dull.

- The game starts at a low level of difficulty and throughout adjusts to current player performance. Evolution of difficulty follows an exponential law, thus advancing in difficulty gets harder as difficulty rises and decreasing gets easier as difficulty drops. This assures that player experiences close to optimum level of difficulty.

- Difference in task difficulty is not made obvious in the game. The tasks both players have to do are similar, the difficulty for the second player being implemented at a deeper cognitive level and well as in input.

- Building up confidence and feeling of competence is important. Patients are given a chance to accommodate with the game through a short training session before the game starts.

- Collaborative helping in-game tasks offer the patients reasons to feel useful and successful. They are not mandatory tasks so that the player does not feel pressured to do it; collaboration tasks also facilitate social interaction.

- Mistakes in games are not treated as big events, and are discreetly signaled.

- Presenting performance statistics is important because getting perfect scores might be a good motivation to engage in more play.

- Therapists have a control screen for the game where they can adjust difficulty levels of the game, specific to each patient's condition.
The game is designed as tabletop game, utilizing a horizontally positioned touchscreen. The game world is scrolling from one side of the table to the other, the direction being determined by which hand is used. The game can be played in both a single player as well as a two-player cooperative play configuration. In the latter configuration a patient and a healthy person could play together (Figure 1).

![Figure 1 - Screenshot of Social CONTRAST](image)

The main objective of the game is to make as many points as possible, each player having to collect the player's own targets while avoiding moving obstacles. The two players control the position on the game platform of their own “characters” (Figure 2 – left), which besides the number indication are distinct in both shape and size.

![Figure 2 – left: Player “character” in-game representation; center: example of obstacles; right: obstacle turning red when hit by Player 1](image)
The patient (hereafter referred to as Player 1) uses a physical artifact on the touch screen to move his “character” around. The movement is achieved by making contact between the artifact and the screen. When the artifact is not in contact with the screen, the player “character” does not interact with the game, being suspended until the contact is reestablished. The healthy player (hereafter referred to as Player 2) controls his character with the keyboard. Player 2 can also perform a “jump” move, similar to the behavior of Player 1’s “character” when the artifact does not touch the screen. The players must avoid moving obstacles that grow in motion speed and complexity as difficulty increases (Figure 2 – center). Obstacles can be avoided either by going through their opening or jumping over them. When Player 1 hits an obstacle, that obstacle turns red, but without making too many visual or psychological disturbances (Figure 2 – right).

While obstacle collision for Player 1 only decreases his score, obstacle collision for Player 2 leads to more drastic punishment, including temporary erratic, inverted or slow movement. This is visually indicated by a red pulsating glow placed around Player 2’s “character” (Figure 3 – left). Player 1 can help Player 2 recover from this situation by moving his “character” over Player 2’s character (Figure 3 – right). This leads to full recovery of control capabilities of Player 2, and also rewards Player 1 with extra points. In order not to pressure Player 1 to engage in rescuing, the movement limitations for Player 2 are active for a limited time, and after this time interval has expired, Player 2 regains his full movement capabilities.

Players also have to collect their own distinct targets, which differ significantly in appearance, in order not to be confused (Figure 4). Player 1 has to collect gray linearly
moving targets or static green targets. Player 2 has to collect colored (green, pink, yellow or blue) targets that follow more ample movements. Collecting a wrong coloured target leads to the same punishment as hitting an obstacle.

![Figure 4 – left: Player 2 targets; right: Player 1 targets](image)

The difficulty in the game is adaptable to current performance of the player. If the player is doing well (is collecting targets), difficulty increases. If the player is experiencing trouble (hits the obstacles) the difficulty level lowers. The score needed to advance in difficulty also increases with each level. The game statistics (targets collected, obstacles hit, saves made) are shown on a scoreboard located on the top of the screen for each player (Figure 5). This is possible because each player has an opposite viewing angle of the screen. Also visual feedback, in the form of in-game messages, is offered during the game, encouraging the players.

![Figure 5 – Player scores](image)

Before starting the game, the patients go through a short easy tutorial in order to accommodate with the game. They are clearly explained what they need to do, and can repeat certain training tasks if necessary. Training isn’t mandatory every time the game starts. At the end of the game players are presented with their score and can judge their progress. Getting perfect scores might be a good motivation to engage in more play.
METHODOLOGY

1. Study design

The main goal of the study was to investigate whether adopting social gaming in rehabilitation tasks can increase stroke patients’ engagement and motivation in carrying out the recovery exercises. A collaborative table-top game was introduced which required participants to capture objects and avoid obstacles, while also helping out their co-player, should he or she get stuck. Two experimental conditions were considered – virtual co-play (hereinafter referred to as “single player” mode) and co-located co-play (hereinafter referred to as “multiplayer” mode). The same version of the game was used so that experience would not be altered by style of game (good single player game vs. bad multiplayer game and vice-versa). Due to the fact that it was out of the scope of the project to develop an AI for the second player to be used in the “single player” condition, the design was manipulated so that participants are made to believe that they are playing the computer, while in reality it is still a human opponent. This method is called Wizard of Oz. As a manipulation check, social presence was evaluated for both cases. Also their gaming experiences were extracted using specialized questionnaires.

This is the independent variable, referred to as “style of play”. The main dependent variables are motivation, engagement and perceived relevance and usefulness of the game for rehabilitation purposes.

In order to investigate the effect the independent variable has on the dependent variables, a within subjects design was considered. One of the advantages of this approach (as compared to a between subject design) is that it can effectively eliminate subject-to-subject variation when considering the effects of different styles of play and thus compensate for the large individual differences that are expected to occur in the target population (in our case, cognitive and physical abilities). Furthermore another important advantage is increased power of the study (caused by the reduction of variability), which allows the reduction of the number of participants. Due to constraints
on the availability of a sufficiently large sample of the target patient population, this proved important for this study.

The within subjects approach also has important drawbacks resulting in carryover effects such as task practice and fatigue. In order to overcome difficulties introduced by these possible confounds, the experiment conditions order have been counterbalanced. This way, carryover effects of opposite directions cancel each other out.

2. Participants

A total of 15 participants (10 male and 5 female) from current recovering patients of Jessa Ziekenhuis (Hospital) in Herk-de-Stad, Belgium, took part in the experiment. Jessa Hospital is one of the most important clinics in the Flemish area of Belgium treating a wide area of patients with highly skilled staff members, in a context of multidisciplinary context. In their Rehabilitation Campus therapists makes use of both classic and novel recovery techniques often collaborating with universities that conduct scientific research on improving rehabilitation therapy.

As main selection criteria, only stroke patients that also undertake upper limb stroke rehabilitation were considered. Each patient had a corresponding Fugl-Meyer Assessment (FMA) index (Fugl-Meyer, Jaasko, Leyman, Olsson, & Steglind, 1975) and Action Research Arm Test (ARAT) index (Lyle, 1981). The Fugl-Meyer scale evaluates the following domains: motor functioning, sensory functioning, balance, joint range of motion, and joint pain. Scoring is based on direct observation of performance. Scale items are scored on the basis of ability to complete the item using a 3-point ordinal scale where 0=cannot perform, 1=performs partially and 2=performs fully. The total possible scale score is 226 and lower scores indicate more severe imparities. The ARAT scale assesses ability to handle objects differing in size, weight and shape. It consists of 19 items grouped into four subscales: grasp, grip, pinch, and gross movement. The total score on the ARAT ranges from 0 to 57, with the lowest score indicating that no movements can be performed, and the upper score indicating normal performance.

Out of the 15 participants, 2 were excluded from the analysis. The first patient was excluded due to extreme answering pattern making her answer scores outliers in almost all investigated dimensions. This was due to clear expressed reticence towards using
computers and their usefulness in rehabilitation. The second patient found it difficult to answer the questionnaires, due to cognitive difficulties, making his responses unreliable.

Descriptive statistics of participants are presented in Table 1.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Age</th>
<th>ARAT</th>
<th>FMA</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>22</td>
<td>57</td>
<td>66</td>
</tr>
<tr>
<td>3</td>
<td>67</td>
<td>50</td>
<td>66</td>
</tr>
<tr>
<td>4</td>
<td>70</td>
<td>23</td>
<td>41</td>
</tr>
<tr>
<td>5</td>
<td>31</td>
<td>40</td>
<td>54</td>
</tr>
<tr>
<td>6</td>
<td>45</td>
<td>57</td>
<td>66</td>
</tr>
<tr>
<td>7</td>
<td>38</td>
<td>44</td>
<td>58</td>
</tr>
<tr>
<td>8</td>
<td>83</td>
<td>50</td>
<td>62</td>
</tr>
<tr>
<td>9</td>
<td>40</td>
<td>37</td>
<td>55</td>
</tr>
<tr>
<td>10</td>
<td>52</td>
<td>48</td>
<td>58</td>
</tr>
<tr>
<td>11</td>
<td>18</td>
<td>37</td>
<td>60</td>
</tr>
<tr>
<td>12</td>
<td>67</td>
<td>19</td>
<td>33</td>
</tr>
<tr>
<td>13</td>
<td>79</td>
<td>57</td>
<td>66</td>
</tr>
<tr>
<td>14</td>
<td>77</td>
<td>55</td>
<td>60</td>
</tr>
<tr>
<td>15</td>
<td>63</td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>mean</td>
<td>53.71</td>
<td>41.36</td>
<td>54.29</td>
</tr>
</tbody>
</table>

Table 1 - Participant statistics

All patients took part in both conditions, playing the game in both “single” and “multiplayer” modes. Order of play was randomized. In the end, 7 participants played “single player” mode first, and 6 played “multiplayer” mode first.

3. Materials

An Iiyama ProLite T2452MTS 24" MultiTouch screen was used as a display for the game (Figure 6, up). The screen surface allowed touch recognition on the contact point. Players can control game elements with virtually any tangible object (from cubes and balls to cups and bottles) as long as it activates the touch screen. In order to maintain the game experience constant for all participants, a medium sized cup was used (Figure 6, down). The cup can be grabbed by its handle and moved around the screen. The cup allowed movement control in the x and y direction (along the axes of the screen), as well
as the z-direction (by picking up the cup, and placing it back again). A plastic adaptor with a piece of fabric oriented towards the screen was attached to the bottom of the cup in order to protect the screen and reduce friction. The movements of the cup were synchronous with the movements of the game representation of the player. The second player was controlled by a computer connected to the screen. The image on both the touch monitor and the computer was mirrored.

![Figure 6 - (up) Screen and input artifacts; (down) Interaction with screen](image)

4. Setting

The layout of the experiment room is presented in Figure 7. The working monitor could not be mounted in the table and thus the screen was a different height level (Figure 8). This made it difficult for participants to rest their elbow on the table. As a consequence, participants were asked to stand (rather than sit) in front of the table and perform the tasks required by the game. Due to the fact that the play sessions were short, this did not represent a problem for most patients although for 2 participants the play sessions were reduced following physiotherapist’s advice. The table was raised at around 70 cm from the ground. A physiotherapist was always present to assist the patient with
technical (instructing the patients about their tasks) and physical (in case the patient experiences any physical trouble during the game) difficulties, if needed. During the tasks, the participants used the same object (the cup) to play the game.

Participants had to complete two series of play, the order of which was randomized. In the “single player” condition (Figure 8, a) the patient was led to believe that the computer controlled the second player while an inconspicuous confederate actually controlled it remotely (Figure 7 – position 1). The participant was left alone to complete the game tasks, and the confederate was positioned behind him, in order to avoid visual contact. In the “multiplayer” condition (Figure 8, b) the participant was made aware that he will play the game together with the confederate, who would be controlling the second player. The confederate now positioned himself in front of the participant (Figure 7 – position 2) giving the game a head-to-head layout. Note that the confederate did not use a tangible interaction object to control the game elements, but used a traditional mouse.
In order to keep the style of play constant, the same confederate was used for both conditions and his involvement did not differ between the two conditions.

5. Measurement

5.1. Objective measures

The game recorded the following in-game statistics:

- Obstacles hit
- Targets collected
- Saves of the second player made
- Total end score.

These scores were shown to players once their round of play is done, in fractional form (e.g. 10 of 20 targets collected) and percentage form (95% obstacles avoided). In order to maintain a positive tone of performance summary, obstacle statistics were presented as a performance (obstacles avoided) rather than failure (obstacles hit).
5.2. Subjective measures

In order to quantify subjective appreciations of the dependent variables, both qualitative and quantitative data were gathered from the participants using self-report questionnaires in written format. Engagement and motivation was measured using a subset of the Game Experience Questionnaire (GEQ) developed by IJsselsteijn et al. (in preparation). This included a 14-question set, featuring 7 dimensions (Competence, Sensory and Imaginative Immersion, Flow, Tension, Challenge, Negative and Positive affect). Each dimension was assessed using 2 questions, each question utilizing a 5-point answering scale (0-not at all, 4 - extremely).

Internal validity of the used scale is presented in Table 2.

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Single Player</th>
<th>Multi Player</th>
<th>Number of Items (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Competence</td>
<td>.634</td>
<td>.698</td>
<td>2</td>
</tr>
<tr>
<td>Immersion</td>
<td>.586</td>
<td>.714</td>
<td>2</td>
</tr>
<tr>
<td>Flow</td>
<td>.566</td>
<td>.765</td>
<td>2</td>
</tr>
<tr>
<td>Tension</td>
<td>.276</td>
<td>.418</td>
<td>2</td>
</tr>
<tr>
<td>Challenge</td>
<td>.292</td>
<td>.664</td>
<td>2</td>
</tr>
<tr>
<td>Negative Affect</td>
<td>.455</td>
<td>.000</td>
<td>2</td>
</tr>
<tr>
<td>Positive Affect</td>
<td>.881</td>
<td>.418</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 2 - Internal consistency of GEQ scale

Social presence was measured using Social Presence in Gaming Questionnaire (SPGQ) (de Kort et al., 2007). The questionnaire contains 17 questions rated on a 5-point scale (0-not at all, 4 - extremely) featuring 3 dimensions (Psychological Involvement – Empathy, Psychological Involvement – Negative Feelings and Behavioral Involvement). This also served as a manipulation check and reveal differences between single and multiplayer experiences.
Table 3 presents internal validities for the SPGQ questions.

<table>
<thead>
<tr>
<th></th>
<th>Crombach's α single player</th>
<th>Crombach's α Multiplayer</th>
<th>Number of items (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Empathy</td>
<td>.846</td>
<td>.961</td>
<td>6</td>
</tr>
<tr>
<td>Negative Feelings</td>
<td>.806</td>
<td>.667</td>
<td>5</td>
</tr>
<tr>
<td>Behavioral Involvement</td>
<td>.918</td>
<td>.822</td>
<td>6</td>
</tr>
</tbody>
</table>

Table 3 - Internal consistency of SPGQ scale

The GEQ and SPGQ questionnaires were administered after each session of play, and correspond to the impressions participants had about that particular experience. After the two sessions of play, participants were asked to evaluate the usefulness of the game as a therapeutic tool using the Credibility/Expectancy Questionnaire (CEQ) (Devilly et al., 2000). They were instructed to keep in mind the “multiplayer” version of the game when answering these questions. In terms of qualitative data, open-ended questions about game experience (such as enjoyment of the game or difficulties encountered) and willingness to play the game in other environments and other players were also asked and analyzed.

6. Procedure

Participants were asked to take part in the experiment during their regular rehabilitation training undertaken at the clinic. After their full consent to participate was obtained by the medical staff, they were given instructions about the procedure of the experiment, what tasks needed to be completed and what was expected from them. Participants were asked to stand in front of the table where the display was located. Before the experiment started, the patients were introduced to the game and the interaction style, and were offered a short tutorial where they familiarized themselves with the gameplay, the input mechanisms, game elements and goals of the game. The tutorial consisted of tasks that needed to be completed, gradually introducing the player to control, target collection, obstacle avoiding, helping player 2 and scoring.
A short demo was presented before each task, accompanied by verbal explanations. The therapist could decide to repeat a certain task if the participant did not prove sufficient comprehension and ability. This tutorial had a double role: to help participants understand the game and to build up their confidence in their abilities to be successful. During instructions, it was made very clear that the game is about collaboration between players and not competition and that the second player would be controlled once by the computer and once by the confederate. The tutorial was then followed by two separated sessions of play the order of which had been randomized. Each session of play corresponded to an experiment condition. The therapist could adjust the duration of each session, based on the momentary physical and cognitive load of the participant. A normal session of play was 3 minutes and 30 seconds. Except for 2 participants who were recommended shorter sessions (2:00 and 2:30 respectively) by their therapists, all participants had normal play sessions. After each play session, patients were asked to fill in a short set of questions regarding their experience, consisting of the GEQ and SPGQ questionnaires. For the last part of the questionnaires, participants were asked to answer the CEQ questionnaire and general questions. For this last set they were specifically instructed to keep in mind the multiplayer session of play. In case there was time left, a short debriefing took place, and patients were asked if they wanted to play the game again for another minute. In case of an affirmative answer, their choice for game style of play was recorded. The experiment timetable is presented in Table 4.

<table>
<thead>
<tr>
<th>Duration</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 MINS</td>
<td>INTRO</td>
</tr>
<tr>
<td>4 MINS</td>
<td>GAME TUTORIAL</td>
</tr>
<tr>
<td>4 MINS</td>
<td>SESSION #1 OF PLAY</td>
</tr>
<tr>
<td>6 MINS</td>
<td>SESSION #1 OF QUESTIONS</td>
</tr>
<tr>
<td>4 MINS</td>
<td>SESSION #2 OF PLAY</td>
</tr>
<tr>
<td>7 MINS</td>
<td>SESSION #2 OF QUESTIONS</td>
</tr>
<tr>
<td>3 MINS</td>
<td>FINAL DISCUSSION AND DEBRIEFFING</td>
</tr>
</tbody>
</table>

**TOTAL: 30 MINS**

Table 4 – Experiment timetable
RESULTS

This section presents the gathered results of the experiment. It includes the outlier analysis, manipulation check, analysis of both subjective and objective measurements and qualitative behavioral reports.

As presented earlier, the following data was gathered from participants:

- subjective appreciations of game experience and social presence
- perceived efficiency of the game in therapy
- game performance measures

1. Outlier analysis

Out of the total 15 participants, 2 participants had to be excluded from the analysis. One participant’s extreme response behavior made her an outlier in most investigated dimensions with a potential to bias the following analysis. Another participant did not show a clear understanding of the contents of the questionnaires, due to limited cognitive possibilities, making his responses unreliable and thus were excluded from further analysis. The rest of the analysis was concluded without including the scores from these two participants.

2. Manipulation check – Social presence

In order to investigate the experiment’s main manipulation effect (presence or (virtual) absence of the second player) a Social Presence Questionnaire was administered after each session of play for the two conditions. The results presented in Table 1 illustrate that there was a marginally significant difference (p=0.089) on the Empathy dimension, denoting that participants experienced more empathy for the second player in
the multiplayer session. Although a slightly higher level of behavior involvement was also recorded for the multiplayer sessions, the difference with the single player session was not significant. There was no difference for the Negative Affect dimension.

<table>
<thead>
<tr>
<th></th>
<th>Single player</th>
<th>Multiplayer</th>
<th>p</th>
<th>η²</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOCPR_BehInvolv</td>
<td>2.06</td>
<td>2.21</td>
<td>0.586</td>
<td>.028</td>
</tr>
<tr>
<td>SOCPR_Empathy</td>
<td>2.2</td>
<td>2.56</td>
<td>0.089</td>
<td>.222</td>
</tr>
<tr>
<td>SOCPR_NegAffect</td>
<td>1.07</td>
<td>1.03</td>
<td>0.781</td>
<td>.007</td>
</tr>
</tbody>
</table>

Table 5 – Means for SPGQ

3. Game Experience

A repeated measure one-way ANOVA was performed to investigate differences between the investigated dimensions of GEQ in the two gameplay conditions. Independence of observations assumption for ANOVA was respected and sphericity was not problematic since repeated factor does not have more than 2 levels.

Normality statistics are presented in Table 6.

<table>
<thead>
<tr>
<th></th>
<th>SINGLE PLAYER</th>
<th>MULTIPLAYER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Skewness</td>
<td>Kurtosis</td>
</tr>
<tr>
<td>GEQ_Immersion</td>
<td>-1.328</td>
<td>1.875</td>
</tr>
<tr>
<td>GEQ_Competence</td>
<td>0.429</td>
<td>-0.397</td>
</tr>
<tr>
<td>GEQ_NegAffect</td>
<td>2.179</td>
<td>3.223</td>
</tr>
<tr>
<td>GEQ_Flow</td>
<td>-0.028</td>
<td>-0.755</td>
</tr>
<tr>
<td>GEQ_Tension</td>
<td>1.134</td>
<td>1.398</td>
</tr>
<tr>
<td>GEQ_PosAffect</td>
<td>-0.661</td>
<td>-0.883</td>
</tr>
<tr>
<td>GEQ_Challange</td>
<td>0.037</td>
<td>-0.562</td>
</tr>
</tbody>
</table>

Table 6 – Normality statistics for GEQ dimensions.

The only significant difference between conditions was GEQ_Tension ( F(1,12) = 10.329, p<.01), participants reporting significantly lower levels of tension for multiplayer
than for single player condition. Figure 9 and Table 7 present the means for the investigated dimensions. Including age, gender or physical abilities, as covariates, did not change the any of the outcomes of the analysis.

![Game experience Questionnaire Dimensions](image)

**Figure 9 – GEQ and SPGQ dimensions for the two sessions of play**

<table>
<thead>
<tr>
<th>GEQ Dimension</th>
<th>Single player</th>
<th>Multiplayer</th>
<th>p</th>
<th>η²</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEQ_Immersion</td>
<td>3.34</td>
<td>3.26</td>
<td>0.739</td>
<td>.010</td>
</tr>
<tr>
<td>GEQ_Competence</td>
<td>3.03</td>
<td>2.73</td>
<td>0.193</td>
<td>.137</td>
</tr>
<tr>
<td>GEQ_NegAffect</td>
<td>0.15</td>
<td>0.11</td>
<td>0.753</td>
<td>.009</td>
</tr>
<tr>
<td>GEQ_Flow</td>
<td>2.84</td>
<td>2.57</td>
<td>0.252</td>
<td>.108</td>
</tr>
<tr>
<td>GEQ_Tension</td>
<td>0.69</td>
<td>0.34</td>
<td>0.013</td>
<td>.415</td>
</tr>
<tr>
<td>GEQ_PosAffect</td>
<td>3.11</td>
<td>3.03</td>
<td>0.721</td>
<td>.011</td>
</tr>
<tr>
<td>GEQ_Challange</td>
<td>2.19</td>
<td>2.38</td>
<td>0.209</td>
<td>.128</td>
</tr>
</tbody>
</table>

**Table 7 – Means for GEQ**

4. **Subjective appreciation of therapy credibility and patient expectancy**

Table 4 presents patients answers about perceived therapy credibility and expectancy. Questions 1,2,3 and 4 are about what the patient thinks about the therapy, while questions 5 and 6 are about what the patient feels about the therapy. Questions 1,2,3 and
5 are recorded using a 9 scale Likert (not at all … - very …) and questions 4 and 6 use a 10 point scale starting representing percentages.

<table>
<thead>
<tr>
<th>Question</th>
<th>Score (std. dev.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. How logical does the therapy offered to you seem?</td>
<td>6.54 (1.50)</td>
</tr>
<tr>
<td>2. How successfully do you think this treatment will be in reducing your symptoms?</td>
<td>6.08 (1.93)</td>
</tr>
<tr>
<td>3. How confident would you be in recommending this treatment to a friend?</td>
<td>6.51 (1.31)</td>
</tr>
<tr>
<td>4. How much improvement in your symptoms do you think will occur?</td>
<td>69.23% (14.41)</td>
</tr>
<tr>
<td>5. How much do you really feel that therapy will help you to reduce your symptoms</td>
<td>6.38 (1.38)</td>
</tr>
<tr>
<td>6. How much improvement in your symptoms do you really feel will occur?</td>
<td>69.23% (13.82)</td>
</tr>
</tbody>
</table>

Table 8 – Scores (and standard deviations) for the CEQ questions

To be noted that the answers to these questions does not correlate with any of the investigated dimensions or recorded scores.

5. **Player performance scores**

Three types of performance scores were gathered from the game after each session of play: targets collected, obstacles avoided and 2nd player saves made. All of these scores are presented in percentages. Repeated-measures one-way ANOVA was used to investigate differences between all three pairs of score. Although none of the differences in scores were significant, on average the players performed better in the single version of the game in all scoring categories. Controlling for physical abilities indexes (Fugl-Meyer and ARAT) or other variables (such as age or gender) did not modify significance of the differences. Figure 10 presents the score performances for single and multiplayer sessions. Table 9 presents scores means and standard deviations.
The performance scores did correlate with physical abilities and perceived difficulty of the game. Table 10 presents the analysis of bivariate correlation between scores and these indices. The overall score is obtained by averaging scores from both sessions.

**Table 9 – Mean scores and standard deviations for conditions.**

<table>
<thead>
<tr>
<th></th>
<th>Single player (SD)</th>
<th>Multiplayer (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Targets collected (%)</td>
<td>89.00 (9.52)</td>
<td>87.76 (9.82)</td>
</tr>
<tr>
<td>Obstacles avoided (%)</td>
<td>84.24 (17.22)</td>
<td>82.68 (15.42)</td>
</tr>
<tr>
<td>Saves made (%)</td>
<td>84.28 (8.62)</td>
<td>83.45 (8.92)</td>
</tr>
</tbody>
</table>

**Figure 10 - Player performance means**

The performance scores did correlate with physical abilities and perceived difficulty of the game. Table 10 presents the analysis of bivariate correlation between scores and these indices. The overall score is obtained by averaging scores from both sessions.

**Table 10 – Correlations (and p-values) for game performance, physical abilities and perceived difficulty of the game (higher => more difficult).**

<table>
<thead>
<tr>
<th></th>
<th>Targets</th>
<th>Obstacles</th>
<th>Saves</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SINGLE PLAYER</strong></td>
<td>ARAT</td>
<td>Fugl_Meyer</td>
<td>Perceived Difficulty</td>
</tr>
<tr>
<td>Targets</td>
<td>.706 (.007)</td>
<td>.651 (.016)</td>
<td>-.133 (.666)</td>
</tr>
<tr>
<td>Obstacles</td>
<td>.122 (.690)</td>
<td>.226 (.458)</td>
<td>-.506 (.077)</td>
</tr>
<tr>
<td>Saves</td>
<td>.278 (.359)</td>
<td>.332 (.267)</td>
<td>-.245 (.420)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>MULTIPLAYER</strong></th>
<th>Targets</th>
<th>Obstacles</th>
<th>Saves</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARAT</td>
<td>.730 (.005)</td>
<td>.643 (.018)</td>
<td>-.219 (.473)</td>
</tr>
<tr>
<td>Fugl_Meyer</td>
<td>.590 (.034)</td>
<td>.589 (.034)</td>
<td>-.379 (.202)</td>
</tr>
<tr>
<td>Perceived Difficulty</td>
<td>.504 (.079)</td>
<td>.539 (.057)</td>
<td>-.281 (.353)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>OVERALL</strong></th>
<th>Targets</th>
<th>Obstacles</th>
<th>Saves</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARAT</td>
<td>.795 (.001)</td>
<td>.716 (.006)</td>
<td>-.195 (.523)</td>
</tr>
<tr>
<td>Fugl_Meyer</td>
<td>.412 (.162)</td>
<td>.477 (.099)</td>
<td>-.536 (.059)</td>
</tr>
<tr>
<td>Perceived Difficulty</td>
<td>.575 (.04)</td>
<td>.641 (.018)</td>
<td>-.033 (.915)</td>
</tr>
</tbody>
</table>
6. Correlations

Table 11 presents significant correlations between investigated dimensions and game performance, for every session of the game. The correlations were calculated while controlling for Fugl-Meyer and ARAT indexes.

<table>
<thead>
<tr>
<th>Score - Dimension</th>
<th>Correlation (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Targets – GEQ_Competence</td>
<td>.868 (.001)</td>
</tr>
<tr>
<td>Obstacles – GEQ_Tension</td>
<td>-.851 (.001)</td>
</tr>
<tr>
<td>Obstacles – SPGQ_NegativeAffect</td>
<td>-.593 (.054)</td>
</tr>
<tr>
<td>Saves – GEQ_Challange</td>
<td>590 (.056)</td>
</tr>
<tr>
<td>Computer Literacy – GEQ_Immersion</td>
<td>-.609 (.047)</td>
</tr>
</tbody>
</table>

Table 11 – Significant correlations between game experience and social presence dimensions and player game performance.

7. Qualitative measures and behavioral observations

In the last part of the questionnaire, participants were asked about their willingness to further play the game, and what their preference for a co-player was. For these questions, more than 1 answer could be selected (for example, a patient could opt to play the game at home as well as at the clinic). For this reason the total number of votes exceeds the number of participants. For these questions, all participants were included. Results are summarized in Figure 11 & 12.
Due to the fact that during the experiment some participants need more time to complete some of the experiment tasks (e.g. completing questionnaires, the training session) and corroborated with their limited time availability, qualitative behavioral measurements were unsystematic and a proper post-experiment interview and debriefing stage could not take place for all participants. In this last part of this section we report impressionistic behavioral data gathered, based on notes made during the experiment.

For 6 of the participants there was still time for another short session of 1 minute. Participants were asked if they wanted to play the game for another minute, since there was still time until the next participant had to start. All participants that were enquired responded positively and when it came to choosing which version of the game they

---

**Figure 11 – Patients preference for place to play the game.**

**Figure 12 – Patients preference for co-player.**
wanted to play, 2 preferred single player, while 4 preferred the multiplayer version. It was possible for 7 of the participants to be asked if they noticed that in the single player condition, the player was actually controlled by a human. All of the participants asked did not notice this manipulation, although they did not expressed amazement.

During gameplay some of the participants articulated their own success and mistakes, but usually on the multiplayer sessions and most of the time for their mistakes (through vocal constructions as “ooh”, “or “ahh”). Out of the 5 participants vocalized their emotions during gameplay, 4 expressed them during the multiplayer sessions. The rest of the participants did not manifest themselves in any obvious ways when making mistakes. One participant found it amusing when the second player got into trouble and another one said that (approximate quotation) the second player “should be more careful, since she is very competitive and wants to make a high score”. Overall, most participants did not manifest themselves exuberantly during gameplay.

Another notable aspect during gameplay is that several participants forgot some rules of the game, and needed to be reminded that, for example, the second player had to be saved. Also, at the end of the session, almost all participants expressed interest in the game summary statistics, asking the therapist to interpret them. Some expressed their desire to get a better score on the next session.

None of the participants had any complaints about the cup used for playing the game and depending on how it was most comfortable for them some just grabbed it, some hold it by the handle.
**DISCUSSION**

1. **Main findings and interpretations**

The main objective of this study was to investigate the effects social gaming might have on patients’ motivation to engage in the necessary training tasks required for stroke rehabilitation. The use of specially designed games offers patients novel rehabilitation techniques for doing physical exercises. The proposed approach also tries to offer patients new opportunities to improve social interaction and reintegration during their rehabilitation, and consequently enable a shift towards home-based therapy. A social game that can be used for rehabilitation of upper-limbs has been developed as a tool for investigating the research question, and the participant’s experiences during gameplay were surveyed using questionnaires. The main manipulation of the experiment was the presence or absence of a co-player, in order to investigate how social presence affects game experience. The results show the manipulation was somewhat successful, yielding marginally significant differences on Empathy dimension. The main findings highlight a significant difference in Tension between the two conditions, participants reporting to be less tense in the multiplayer condition than the single player condition. Other results show that in the multiplayer condition participants were more Challenged, felt less Competence, and experienced less Flow, when compared to the single player condition, although differences were only marginally significant. There were no differences in experienced feelings of Negative or Positive Affect and Immersion between the two conditions.

The findings that patients were more empathic towards the second player and felt less tense while playing the game in the multiplayer condition could yield a higher level of relatedness. This dimension of the SDT model was the essential improvement point for the social aspect of the game towards higher intrinsic motivation. The other dimensions were out of the scope of investigation for this study but were considered during the game design phase. For example, supporting the kinds of movements that are typical for ADLs could enhance feelings of autonomy in patients. Moreover, proper difficulty level
adjustment can make patients feel more competent at the various tasks, in particular when such adjustments are made implicitly (through, e.g., role differentiation between patient and non-patient) rather than explicitly (through differences in difficulty level for patient versus non-patient). Also in line with social facilitation theory participants reported feeling slightly more challenged and less competent during the multiplayer sessions (although differences were only marginal significant). It would be expected though that this effect would diminish with longer exposure to the game. The mere presence of the second player might have an inhibiting effect although tension levels were lower in the multiplayer condition. Further research can investigate whether playing against strangers (as it was the case in this study) yields different stress levels that playing with close friends or family. Investigating participant performance scores also shows the presence of this effect, since players performed, on average worst in the multiplayer condition (although differences were not significant) although literature has reported increased performance levels in multiplayer settings (e.g. Ballester et al. (2011) and Loureiro et al. (2010)). This shows how important sustained psychological support during the task might be, and that the healthy player has the possibility to offer it through a game layout that facilitates social interaction. Social facilitation can also explain the slightly lower levels of Flow in the multiplayer conditions. A cause for the levels of flow experienced are a consequence of higher levels of challenge with a consequence of a lower level in competence, according to theory of flow.

Another explanation for the difference in dimension levels could be concluded from the behavioral observations, where participants expressed themselves more vocally in the multiplayer condition. Correlations between Saves made and Challenge have opposite directions for the two conditions. This could be interpreted in the light that saving the other player adds to challenge appreciations, in the multiplayer condition, saves made make the game seem less challenging, although causality cannot be implied. Also while for single player the main factor that reduces tension is obstacle avoidance, in the multiplayer condition tension reduction is related to Saves made, the main collaborative and social activity. Another interesting correlation shows that in single player mode, the more targets participants the more competent they felt. It seems that for single player participants were more focused on target collection and obstacle avoiding (more single player profile activities), while for multiplayer participants the number of saves made (and thus the interaction with the second player) was more determinant for their experience.
In line with other research presented on rehabilitation games, participants had a general positive response to the approach in both reported credibility of therapy as well as in qualitative observations and remarks. This is illustrated by the high ratings this rehabilitation method received on the CEQ questionnaire.

The high and meaningful correlations between the physical performance indexes (ARAT and FMA) show that the game has potential of developing as a diagnostics tool besides its therapeutic qualities. This bodes well for the use of such game in rehabilitation, where performance on the game can be deemed to be clinically meaningful. Physiotherapists can also adjust difficulty levels of the game according to prior evaluation of patients.

The high preference for family and friends as co-players (as opposed to therapists or other patients) and the home as the preferred setting for playing the game (as opposed to the clinic) presented in the results shows an openness towards shift in rehabilitation practices. Although the evidence presented in this research is not conclusive, there is great potential for integrating social games in rehabilitation therapy.

2. Limitations of current research

For higher ecological validity of the results presented in this research, the ideal scenario for the experimental setting would be patients’ home environment. Also, in terms of co-players, the desired sample would be patients’ family members, or close circle of friends (in order to have, for example optimal levels of empathy, encouragement, and emotional involvement from the second player). Due to limited access to target patient population and the fact that this was a first exploratory study, the experiment had to take place in a clinical setting with confederates taking the role of the second player thus limiting the richness and meaningfulness of the social interaction between players.

The lack of strong differences between conditions might have been caused by the subtle manipulation. It might be the case that the presence of the confederate in the room for the single player condition, although they were out of sight, might have had an effect, even though no clue was given about the confederate’s activity and participants were explicitly told they were playing against the computer. A different problem with the manipulation could arise from the fact that the confederate was a non-Dutch speaker,
and only a few patients could communicate in English, thus limiting social interactions somewhat.

Another limitation for the research was the reduced number of participants and the relatively short amount of time they could take part in the study. This is a problem in general for research in this area. It might be the case that the time participants had for each session of play was too short in order to truly have different experiences in the two conditions. Due to this limited time, the number of questions included in the questionnaires was limited and narrowed investigated psychological dimensions.

3. Future recommendations

In order to have a more clear understanding of the impact social elements included in rehabilitation games have on patients motivation within the recovery process a few improvements can be made to the current research:

- Include a larger number of patients, in order to gain statistical power of the results. Ideally, more patient populations should be considered.
- Test the game in a home environment, and preferably over a longer period of time in order to observe physical improvements as well.
- Strengthen the Wizard of Oz type manipulation by having the second player play remotely (from another room) in the single player condition.
- Have longer sessions of gameplay; in order to do this, the game needs to be more complex not to induce boredom or a sensation of repetition. The current game was developed so that it remains interesting for the short sessions of play.
- Systematically record player behaviors during gameplay, and allow more time for a more systematic qualitative interview afterwards, since such qualitative data they might offer better insights into the experiences players have.
- Explicitly test for intrinsic motivation (utilizing, e.g., the Intrinsic Motivation Inventory); this presumes higher times for questionnaire completion, but might offer a more complete picture of how social elements influence motivation.
• Experiment with different input types and artifacts. Also, screen position might have different orientations (in all axes) to extend physical movements the patient undertakes

• Offer patients the possibility to customize their experience and have a representative avatar in the game. This can create a more personal experience and give more meaningfulness to the activity. As extra motivation to do well in the game (and thus exercise more) players can compare their scores with other patients, friends or relatives.

4. Final remarks

The increasing number of stroke survivors, which are discharged from hospitals and clinics, are usually looked out for by their families or close friends who become important actors in their recovery process. Engaging in socially rich and therapeutically meaningful activities with those that have them in care might intrinsically motivate patients to carry on the rehabilitation with greater optimism and success.

The current research found promising positive effects of social presence in game enjoyment. Also the manipulation was somewhat successful, although it can be further improved to give even more conclusive results. Patients had overall good appreciation of the game and interaction styles and the results did not show patients had negative feelings towards the game. Overall (averaging experiences in both conditions), the levels of challenge competence and flow were at a reasonable level. The very high correlation of game performance with clinical measures shows a high ecological validity of the game. Patients stated preference for playing the game with friends and family in home environments shows the potential for a shift in rehabilitation practices. Because this study was one of the first exploration in this area further investigation of the effects of social gaming in rehabilitation therapy is certainly worth pursuing further.


ANNEX

EXPERIMENT SCRIPT:

Phase 1 – INTRODUCTION (3 minutes)

We are testing a new game for physical rehabilitation therapy. Please stand in front of the screen and hold this object (the one they will use for playing). For this experiment you will have to play the game and answer some questions about your experiences while playing. You play the game twice for a short period, and after each round you will be given a set of questions to answer.

Throughout the experiment, feel free to ask any questions that you might have regarding the game or the questions. If at any point you feel tired or unwell, please tell us and we will immediately stop the experiment. It is no problem if at any point you wish to stop. These sessions and the data we collect are confidential and will be used only in the scope of this project.

Thank you for participating, and let’s begin by a short introduction of the game.

Phase 2 – TRAINING (5 minutes)

You will now be guided through a short introduction of the game and training.

Task 1: The circle you see on the screen is the player you will control throughout the game. His name is “number 1”, and has the number “1” written on it in the center. In order to move it, you need to place this object on the surface of the screen and move it around. If you lift the object from the surface, the player will “jump”, and will be depicted by a transparent circle. While the player jumps, it will not interact with the game elements, like obstacles or targets.

Task 2: Your main objective in the game is to collect targets. These objects travel from the right/left side of the screen, and have a round shape (observe on the screen). In order to collect the target, you must move towards it, and “touch” it. As you do, the target will be “collected” and it will disappear from the screen.

Task 3: Your other objective is to avoid obstacles. The obstacles you encounter are of two types: ones that you need to avoid by going through the opening, and the ones that you need to avoid by jumping over them. As you recall, jumping is performed by lifting the object you hold from the screen and then putting it back down once the obstacle has passed.

Task 4: Alongside you there will be another player, called “number 2”. **HE WILL BE CONTROLLED BY THE COMPUTER.** He also has to collect his own targets, and avoid the obstacles. At some point, because he has done something wrong, he get’s in trouble. This is represented by the red glowing circle around him. Due to this, he has difficulties. In order to recover he needs your help. You can provide him with help the same way you collect targets, by approaching him and “touching” him. When you do that he returns to normal, and the red glow disappears. If you do not rescue him fast enough, he will recover on his own.
**Task 5:** I will now talk about the in-game scoring. When you collect the target you get +2 points to your score (as it is shown on the screen). When you hit an obstacle you get -1 (one point deducted) points. When you rescue Number 2, you get +3 points (as it is shown on the screen). Number 2 also collects its own targets. They are different from your targets. They are in the form of a ring and are colored. Also they move differently. You can ignore these targets, as you cannot interact with them. At a certain point, a special target appears. It’s similar to the regular target except that this one is green and static (it does not move). This targets value is equal to the number of points player 2 collected until that moment. Thus your score cumulates (your scores are added together), because the game is about cooperation.

If you’re ready we can start the game

*Phase 3 – PLAY 1 (considering it SINGLE PLAYER CONDITION) (4 minutes)*

For this session you will play **BY YOURSELF. THE COMPUTER WILL CONTROL NUMBER 2.** Please remember that this game is about collaboration, **IT IS NOT A COMPETITION.** You are not playing against each other, but together. Your scores will be cumulated in the end.

*Phase 4 – QUESTIONS 1 (5 minutes)*

Please answer the questions on the first two pages of the questionnaire set. These are about the experiences you had while playing. Please select the first answer that comes to your mind.

*Phase 5 – PLAY 2 (considering it MULTI PLAYER CONDITION) (4 minutes)*

(introduce human player 2)

For this session you will play **TOGETHER WITH SOMEONE. HE WILL CONTROL NUMBER 2.** Please remember that this game is about collaboration, **IT IS NOT A COMPETITION.** You are not playing against each other, but together. Your scores will be cumulated in the end.

*Phase 6 – QUESTIONS 2 (7 minutes)*

Please answer the questions on the next four pages of the questionnaire set.

- The first two pages are about the experiences you only had **IN THE LAST SESSION OF PLAY.** Please select the first answer that comes to your mind.
- For the last two pages, **THE ANSWERS ONLY REFER TO THE SESSION WHERE YOU PLAYED TOGETHER WITH A PERSON.**
Phase 7 – ENDING (3 minutes)

(if time allows it)
Thank you for answering the questions. There is still a bit of time left, while we introduce the data in the computer. Would you like to play the game for another minute? If yes, which condition would you like to play the game in? Alone and have the computer play Number 2 or together with the human player?

(after it is done)
Before you leave, please let us know what you thought about the game in general? Did you notice anything regarding the second player in the game? Did you realize that he was also controlled by the human in the condition when you played alone? This is what our research was about, to see if patients have a better experience while playing together with person than playing alone.
Thank you for participating!
**QUESTIONS:**

Duid voor elk van de items aan hoe jij je voelde tijdens het spelen. Doe dit met behulp van de volgende schaal.

<table>
<thead>
<tr>
<th></th>
<th>Niet</th>
<th>En slechts een beetje</th>
<th>Enigszins</th>
<th>Behoorlijk</th>
<th>Heel erg</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ik was geboeid door het verhaal van het spel</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>Ik voelde me succesvol</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>Ik voelde me verveeld</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>Ik vond het indrukwekkend</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>Ik vergat alles om me heen</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>Ik was gefrustreerd</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>Ik vond het saai</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>Ik was prikkelbaar</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>Ik voelde me vaardig</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>10</td>
<td>Ik was helemaal geabsorbeerd</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>11</td>
<td>Ik voelde me tevreden</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>12</td>
<td>Ik voelde me uitgedaagd</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>13</td>
<td>Ik moest er veel moeite in steken</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>14</td>
<td>Ik voelde me lekker</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>15</td>
<td>Ik leefde mee met de ander</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>16</td>
<td>Mijn handelingen hingen af van de handelingen van de ander</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>17</td>
<td>De handelingen van de ander hingen af van mijn handelingen</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>18</td>
<td>Ik voelde me verbonden met de ander</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>19</td>
<td>De ander lette op mij</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>20</td>
<td>Ik lette op de ander</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>21</td>
<td>Ik was jaloers op de ander</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>22</td>
<td>Ik vond het gezellig met de ander</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>23</td>
<td>Wanneer ik blij was, was de ander blij</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>24</td>
<td>Wanneer de ander blij was, was ik blij</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>25</td>
<td>Ik beïnvloedde de stemming van de ander</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>26</td>
<td>Ik werd beïnvloed door de stemming van de ander</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>27</td>
<td>Ik bewonderde de ander</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>28</td>
<td>Wat de ander deed, beïnvloedde</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>
Wat ik deed
29 Wat ik deed, beïnvloedde wat de ander deed 0 1 2 3 4
30 Ik was wreakzuchtig 0 1 2 3 4
31 Ik had leedvermaak 0 1 2 3 4

We zouden het op prijs stellen als u een indicatie geeft hoeveel dat u gelooft, op dit moment, dat de therapie die u ontvangt uw situatie helpt verbeteren. Geloof heeft normal twee aspecten: (1) wat iemand denkt dat zal gebeuren (2) wat iemand voelt dat zal gebeuren. Deze kunnen soms overeenkomen; en soms zijn ze verschillend. In de eerste set van vragen beantwoord met wat u denkt. In de tweede set van vragen beantwoord met wat u echt voelt.

1. Op dit moment, hoe logisch komt de aan jou aangeboden therapie over.
1 2 3 4 5 6 7 8 9
niet alle logische enigszins logisch heel logisch

2. Op dit moment, hoe succesvol denk je dat deze behandeling is in het verminderen van jouw trauma-symptomen
1 2 3 4 5 6 7 8 9
geen enkel nut enigszins bruikbaar very useful

3. Hoe zeker zou je zijn in het aanbevelen van deze behandeling aan een vriend die dezelfde problemen ervaart.
1 2 3 4 5 6 7 8 9
helemaal geen vertrouwen enigszins vertrouwen veel vertrouwen

4. Hoeveel verbetering verwacht je in jouw trauma-symptomen aan het eind van de behandelingperiode
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Voor de volgende set vragen, sluit je ogen voor een moment, en probeer te identificeren hoe je je werkelijk voelt over de behandeling en de kans van slagen. Beantwoord daarna de volgende vragen:

5. Op dit moment, wat zegt je gevoel over het effect van deze therapie op het verminderen van je trauma-symptomen?
1 2 3 4 5 6 7 8 9
1. Hoe ervaren ben je met computers?
   □ Helemaal niet ervaren
   □ Enigszins ervaren
   □ Heel ervaren

2. Met wie zou jij het spel spelen? (selecteer iedereen die van toepassing is)
   □ Ik zou het spel niet spelen
   □ Ik zou het spel alleen spelen
   □ Mijn therapeut
   □ Andere patiënten
   □ Mijn familie
   □ Mijn vrienden
   □ Anderen:________________________

3. Waar zou jij het spel spelen? (selecteer iedereen die van toepassing is)
   □ Ik zou het spel niet spelen
   □ In de kliniek
   □ Thuis
   □ Ergens anders:________________________

4. Maak de volgende zin af: Voor mij was het spel …
   □ te gemakkelijk
   □ enigszins gemakkelijk
   □ enigszins moeilijk (moeilijk genoeg)
   □ te moeilijk

6. Aan het eind van de behandelingsperiode, hoe veel verbetering in jouw trauma symptomen verwacht je volgens je gevoel?
   0%  10%  20%  30%  40%  50%  60%  70%  80%  90%  100%