Design Aspects for Rehabilitation Games for MS Patients

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ABSTRACT
Computer-supported rehabilitation can benefit many groups of patients. However, when designing such a therapy, it is important to take the characteristics of the patient population and the wishes of the therapists involved into account. This paper therefore focuses on the requirements of rehabilitation games for Multiple Sclerosis patients. As we have created a system for rehabilitating Multiple Sclerosis, based on a virtual environment with force feedback, we will discuss how these requirements can be met using the rehabilitation system as an example.

Categories and Subject Descriptors
J.3 [**Computer Applications**]: Life and medical sciences—*health*; H.5 [**Information Systems and Presentation**]: User interfaces; D.2.8 [**Software Engineering**]: Design

General Terms
Design, Human factors

Keywords
Rehabilitation, virtual environments, haptics

1. INTRODUCTION
Multiple Sclerosis (MS) is a chronic progressive disease of the central nervous system. Depending on the distribution of lesions within the brain, MS may clinically present with impairments of strength, muscle tone, sensation, co-ordination, balance, bladder and bowel function, as well as visual and cognitive deficits, often leading to severe limitations of functioning in daily life. Studies of exercise therapy, focused on balance and walking outcome parameters, have shown a beneficial effect regarding muscle strength, exercise tolerance level, functional mobility and quality of life, while no important deleterious effects were reported [2]. Very few studies have properly investigated the therapeutic potential of arm training in persons with MS. Because training duration and training intensity are considered to be key factors for a successful neurological rehabilitation [5], rehabilitation robotics are introduced to provide additional exercises that can be performed independently of the therapist. Crucially, the patient has to be motivated, and keep being motivated to continue the training regime. We are investigating the value of force-feedback assisted rehabilitation of the upper extremities in persons with MS [4] and how such technologies can be applied in a self-motivating way. More concretely, a virtual environment (VE) has been realized, which provides the patients with training tasks to be carried out and monitors their progress and success rate [3].

In order to realize a good rehabilitation therapy, it is important to take human factors into account. Therapy can only be successful if the patients have to perform rehabilitation tasks, which are challenging, but can still be executed by a patient. Therefore, limitations of the patients' abilities, both physical and cognitive, must be taken into account. Furthermore, rehabilitation tasks must be repeated often in order to be effective. It is therefore important to take motivational aspects into account. This can be realized by providing game-like rehabilitation tasks. Finally, the therapists must be able to define and adjust the patients' therapies. Therefore the rehabilitation system must support the therapists in determining the patients' progress and to make the necessary corrections.

This paper discusses the design aspects that must be taken into account when creating rehabilitation games for MS patients. The requirements from the patients' and therapists' point-of-view are elaborated on. Finally, we will discuss how our solution for the rehabilitation of the upper limbs meets these requirements.

2. REQUIREMENTS
Different aspects must be taken into account when creating rehabilitation games. Both the patients and the therapists must be able to work with the system efficiently in order to achieve the desired results from the therapy.

2.1 Patients' Requirements
Multiple Sclerosis is a disease, which typically worsens in several stages. Patients, which have troubles using their arms, already have the disease in a severe form and are typically elderly people. Often, these people are bound to a wheel chair, and have cognitive problems. A rehabilitation system must therefore be easy to understand and use. In order to give feedback of the patients' movements in 3D, such a system should also provide feedback in 3D. It is however, difficult for these patients to have insight in 3D movements. Furthermore, patients have difficulties using their arms. This includes both problems with muscle strength as with muscle control. The system must therefore be able to also support patients with severe difficulties. Finally, patients must not need to control menus and other typical UI elements as many patients have no to little experience with computers. Even patient who are familiar with this kind of

interface, are not always able to control them in an efficient manner due to their muscle problems.

These leads to the following requirements:

1. the game play must be easy to understand
2. feedback about users' movements must be clear
3. patients who have muscle difficulties must be supported by the game
4. "classical" UI elements, such as menus and slider must be avoided

Next to these requirements, it is important to take the training frequency into account. In order to be successful, a patients needs to train three times per week, during several weeks or even months. As games must be simple in order to satisfy the above-mentioned requirements, they run the risks often getting boring soon. The games must therefore pose enough challenges, without becoming to difficult. Furthermore, the patients must receive feedback about their performance. They need to get the feeling that they are progressing. This can be achieved by awarding the patients when they make progress. In order to not discourage patients who have many difficulties, the amount of progress that needs to be achieved must be adapted to patients' abilities. Alternatively, different types of awards can be defined, ranging from small awards for limited progress to big awards for good progress.

These leads to the following requirements:

5. the difficulty must be adapted to the different patients
6. the games must be challenging
7. progress must be awarded
8. all patients must be able to make progress

Finally, in order to further motivate patients, extra incentives such as social interaction and storytelling [1] can be included in the game. These are not strictly necessary, but are useful to improve the games.

These leads to the following requirement:

9. extra motivational aspects can be taken into account

2.2 Therapists' requirements

In order to meet the patients' requirements, it is important to enable the therapists to define the therapy sessions. As games can include many parameters, including force feedback settings, standard difficulty levels must be provided. Of course, the therapist must be able to assess the patients' progress in order to be able to determine the most suitable settings. Feedback about the patients' progress should therefore also be provided for the therapist.

These leads to the following requirements:

10. therapists must be able to define therapy sessions
11. therapists must be able to assess a patient's progress
12. therapists must be able to change difficulty settings for an individual patient

3. REHABILITATION GAMES

We have created a system for provding MS patients with rehabilitation games. These games take place in a virtual environment, which acts upon a patient's movement. For this purpose, we use a HapticMaster [6] as it can provide the patient with force feedback.

The therapy system provides two types of games: simple games, which clinically trains a particular movement, and advanced games, which combine several movements. Figure 1 shows an example of a simple game, called lifting, where the patient needs to move an object up and down between two targets.

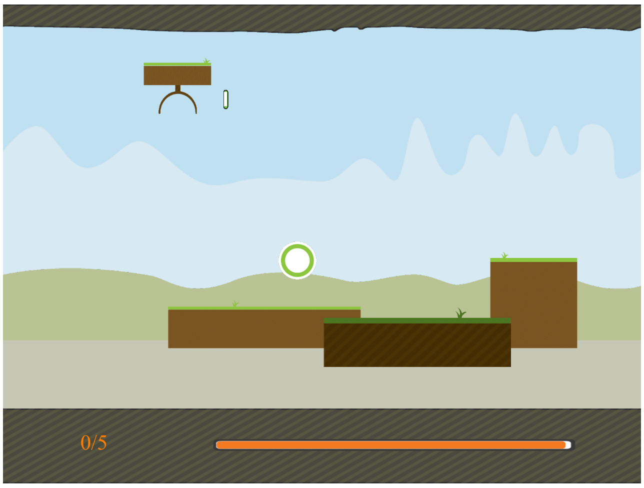

Figure 1: Lifting game

As this game only trains one pariticular movement, it is not difficult to learn. Furthermore, the target areas have a shape that indicate that the circle, controlled by the patients, needs to be docked there. This games thus ensures requirement 1 (*the game play must be easy to understand*). As there is a one-to-one mapping of a patient's movement to the movements of the circle, requirement 2 (*feedback about users' movements must be clear*) is at first sight also satisfied. This is however not sufficient: movements in the 2D plane, in which the targets are located, are clear to the patient. However, the patient can also move forward and backward, which can be difficult to understand. Therefore, the circle changes color according to the forward and backward movement. If the patient holds the circle in or near the plane, the circle is colored green. When the distance with the plane becomes larger, the circle is colored orange, and finally red when it is too far away. This color system ensures that requirement 1 is met.

In order to satisfy requirement 3 (*patients who have muscle difficulties must be supported by the game*), gravity compensation is implemented: the HapticMaster constantly applies a force, which counteracts the weight of the patient's arm. Furthermore, patients, who experience much difficulty can be guided towards the path that they should follow or even to the target itself. This principle allows to define several difficulty levels, thus ensuring that requirement 5 (*the difficulty must be adapted to the different patients*) is met.

As a game's difficulty can be adjusted for each patient, the patients must perform at their best in order to achieve the goal. This can further be realized, by changing the number of times the target must be successfully reached and the time that is available to achieve this. Hence, requirements 6 (*the games must be challenging*) and 8 (*all patients must be able to make progress*) are met.

We realize however that simple games may become boring after a while. The next section will therefore elaborate on ways to motivate patients to play these games.

4. MOTIVATIONAL ASPECTS

Although the simple games can become boring, it's important for the patients' progress that they play them. Patients must therefore be awarded to play these game. In order to support this, we envision an overall game concept (see figure 2. In this concept, patients can unlock more challenging and engaging games by successfully finishing a simple game. This way, requirement 7 (*progress must be awarded*) is satisfied. Furthermore, by incorporating themes (common elements in different games), a story behind the games can be hinted upon. This meets requirement 9 (*extra motivational aspects can be taken into account*). As a patient can move from one game to another, by simple moving his arm in the direction of the next game, menu's are avoided. This satisfies requirement 4 (*"classical" UI elements, such as menus and slider must be avoided*).

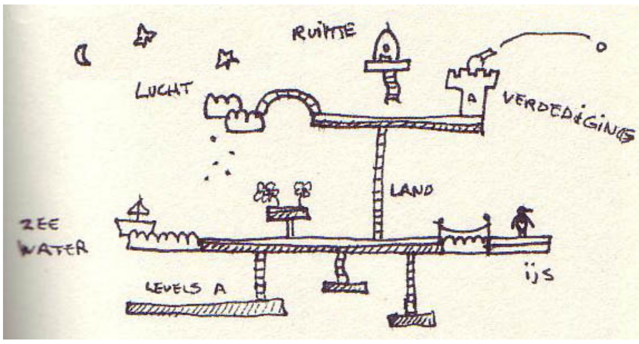

Figure 2: Overal game concept

In order further satisfy requirement 9, we are investigating the usefulness of collaborative games. For this purpose, we have created a game, where two patients (or a patient together with a family member) can play together. Both players can push one side of a beam upwards, as depicted in figure 3. By controlling the height of both sides, a ball can roll over the beam and hit some stars, which represent points. Both the HapticMaster as a WiiMote can be used as input device. More information about this collaborative game can be found in [7].

5. THERAPIST INTERFACE

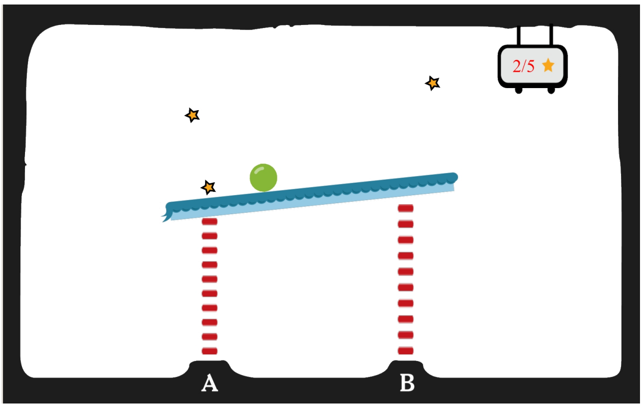

Figure 3: Collaborative game

As MS patients have a different progression of the disease, each patient needs an individual training program in order to have a successful rehabilitation. The therapist therefore needs to be able to create these personalized training programs. We have created an interface that allows therapists to do this (see figure 4). The left column in this figure contains all games that are currently available. The therapist can compose therapy sessions by choosing them from the left column. The gray area in the top of the figure shows the selected games. This process ensures that requirement 10 (*therapists must be able to define therapy sessions*) is met.

In the middle of the figure, the therapist can change the difficulty level according to three axes (general parameters, such as the workspace size, haptic parameters, such as the size of the forces, and the training volume parameters, such as the number of repetitions). This way, the difficulty can be personalized. For endurance training, the haptic difficulty will be kept low whilst the training volume category will be made high. Power training on the other hand requires a high haptic difficulty with fewer repetitions. This way of working satisfies requirement 12 (*therapists must be able to change difficulty settings for an individual patient*).

At this moment, however, our system is not yet able to provide the therapist with good feedback about the patients' progress. This feedback will be defined together with therapists in the coming months. Therefore, we are not yet able to meet requirement 11 (*therapists must be able to assess a patient's progress*).

6. CONCLUSIONS

This paper presented different aspects that must be taken into account when creating a game for the rehabilitation of MS patients. Although, these requirements are very diverse, it is possible to take this set into account. We are currently creating a system for rehabilitating MS patients. Some first game have been realized, which are able to meet most of the requirements. In a next phase, more challenging games and an overall game concept will be realized. Together with feedback about the patients;' progress for evaluation purposes, these will ensure that the remaining requirements are also satisfied.

7. ACKNOWLEDGMENTS

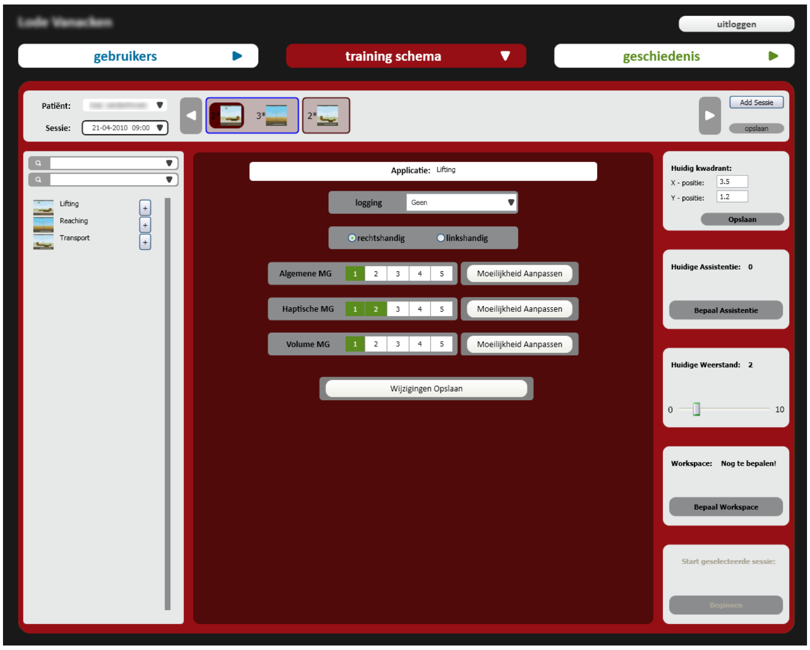

Figure 4: The therapist interface. The interface is in Dutch as the target audience consists of native Dutch speakers.

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