Using the Phantom Device for Rehabilition of the Arm in MS Patients: a Case Study

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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 [1]. 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 [2], we are investigating the value of robot-assisted rehabilitation of the upper extremity in persons with MS. More concretely, a virtual environment (VE) has been realized, which provides the patients with the training tasks to be carried out and monitors their progress and success rate. Not only visual feedback is presented in this VE; in order to train the patients with the execution of natural movements, a Phantom device is used, which generates force and thus proprioceptive feedback.

Below, we summarize the objectives of this research and we describe the system setup. Furthermore, we elaborate on the (multidisciplinary) research method being used to assess the potential of the Phantom as a training device in this context. Design and implementation of training tasks, and data logging, supporting measurement of the training effect as well as assessing usability, for the patients and the therapist are covered. We conclude with initial experiences of patients interacting with a proof of concept prototype environment.

Objectives and overall approach

The overall aim of our investigation is to assess the potential of the Phantom as a training device in the context of rehabilitation of MS patients with upper limb dysfunction. Besides measuring the effect of a Phantom-assisted training approach (Does the value of some quantifiable parameters such as muscle strength and arm function improve after repeated training?), we want to judge some usability issues such as acceptance of this kind of training program by MS patients.

In order to estimate the effect of the repeated Phantom-assisted tasks, it is important to design appropriate movement tasks (e.g. difficulty level allowing for effect measurements and allowing for as much carry over to actions in daily life as possible). Therefore, the team consists both of rehabilitation and computer scientists, working in a close cooperation with MS patients and clinical therapists of a rehabilitation centre. During the design and realization of the training tasks, it is important to pay attention to the possibility to measure the patient's behavior (e.g. by means of data logging with respect to movements with the device) and to "steer" the patient's behavior when performing the task by facilitating or obstructing the user's movements through the generation of appropriate forces by the Phantom device. This allows for personalization depending on the present capabilities of the patient and to change the training level.

A 3-week robotic training program is being set up, in which the patients perform the training tasks on a regular basis, i.e. approximately half an hour daily. At the beginning and at the end of this period, the user's arm motricity and functionality is tested using standardized neurological evaluation and arm function tests in order to judge if the patients' capabilities for executing manual tasks in daily life have been improved.

System setup

The training system consists of a standard PC and a Phantom device. In order to provide the patients with a large enough working field, a Phantom 1.5 is used in combination with a 19" monitor. This Phantom device is handled through a pen-like handle and allows tracking the handle's tip in 6 degrees-of-freedom and can generate forces in 3 degrees-of-freedom. The currently realized VE supports three training tasks (see figure 1).

In a first task, the patient sees a top-view of a road. A virtual car, steered by the Phantom device, has to be moved to from a start position via a various trajectory to an end position on the road. The patient is aided in this task by restricting the Phantom movement to the 2D plane in which the road is located. Furthermore a force is applied, which attracts the car to the centre of the road. The size of this force can be changed in order to change the difficulty of the task. Optionally, a viscosity force can be used to require a higher force from the patient, or to assist patients with tremor.

For the second task, users have to grab a book lying on a shelf

Figure 1. *Training tasks*

and place it in a bookcase. The forces used simulate the gravity and inertia of the book, which can be adjusted to the patient's capabilities. This task resembles natural object manipulation movements and requires a stable position to grasp the object as well as adaptive motor behavior towards the weight of the object.

The third task is a virtual implementation of the well-known plate tapping test, where patients need to tap two plates as often as possible within a given amount of time, or until 30 reciprocal tappings have been performed.

While performing these interactive tasks, the patients' movements are recorded at a rate of 200 Hz. Although, the analysis of the training data will be limited to the pre and post test, together with one intermediate test, the amount of data gathered is difficult to handle. Therefore, the movement data, the parameters of the tests (e.g. the forces used) and the patients' capabilities will be stored in a relational database. This allows us to filter the data according to specific research interests and to more easily compare different conditions. For instance, using simple queries on the database it is possible to only retrieve the data of patients with a tremor, horizontal trajectories of task 1 or to only compare successfully completed tasks.

User feedback

Up to now, a number of MS patients without or with only mild upper limb dysfunction have used the VE during a single session. The usability of handling the Phantom in the VE was evaluated with the 'System Usability Scale' and adapted questions scored using the Visual Analogue Scale. Subjects did not have difficulties with the visuospatial transformation neither with the force feedback, and commented positively on the VE. One MS patient, who has decreased motor coordination, had difficulties in stabilising her arm at the object in order to grasp the book, demonstrating that this task are likely challenging enough for patients with upper limb dysfunction.

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