Using Haptics Technology to Deliver Motivational Therapies in Stroke Patients: Concepts and Initial Pilot Studies

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Abstract

Attention and motivation are two factors, which are important for motor relearning following stroke. In this paper we introduce and present the novel concepts for the use of haptics technology to deliver therapy to patients with arm impairments following stroke. The results of the ongoing initial pilot studies have shown the feasibility of the system presented here. The new approach will potentially improve the patient's attention and motivation and hence enhance therapy effectiveness.

Key Words

Motor Relearning, Robot Mediated Therapy, Virtual Environments, Perception and Haptic Feedback.

1. Introduction

Stroke is the most common cause of acquired physical disability with estimates of the annual incidence of stroke ranging from 180 per 100,000 in the USA to 200 per 100,000 in England and 280 per 100,000 in Scotland [1]. The incidence rates increase with age, doubling for every 10 years after the age of 45 [2]. Approximately one-third of the patients surviving from a stroke are left with severe disabilities [2]. Evidence has shown that early and intensive physiotherapy improves patient recovery [3] and several authors have already proposed using robots to deliver this type of physiotherapy. [4,5,6]

In the GENTLE/S project (a project under the quality of life initiative of framework 5 of the European Commission to evaluate robot-mediated therapy in stroke rehabilitation) we go further and propose a system based on haptic technology. Haptics have been widely used for different applications ranging from Surgery Simulators [7,8], Virtual Reality-Based Telerehabilitation systems with force feedback [9] to 3D painting interfaces [10].

In the context of haptics and force feedback we have already introduced and implemented a novel mathematical model directed to deliver a system capable of correcting movement in machine assisted stroke rehabilitation. This system can be used for errorless learning techniques and intensive rehabilitation treatment for patients recovering post-stroke. It allows force feedback to be delivered to the patient arm via a 3DOF haptic device (Haptic Master from Fokker Control Systems) strong enough to correct point to point movement within a virtual/real or augmented task oriented therapy.

Following initial input from members of the Young Stroke Association at Stoke-on-Trent, we have enhanced movement realism by implementing a model based on the dynamics of human movement. This model allows the implementation of realistic force feedback in curvilinear 3D movement patterns [11, 12].

We are investigating new ways that will potentially improve patient attention and motivation and therefore enhance therapy effectiveness. The following sections of this paper will present the system developed, the implementation of novel theories and concepts directed to the improvement of motivation and the initial results and feedback obtained from the initial pilot trials with hemiplegic patients.

2. How can we improve patients' motivation?

Attention and motivation are two factors, which are essential for brain plasticity [13]. Plasticity is the ability of the brain to re-organise and adapt to training and experience. This ability to change has therapeutic benefit as the brain has the potential to re-map the area affected by injury/stroke in response to training of skilled tasks and hence allow motor recovery. Lack of motivation has been identified as a major cause of failure to benefit from neurorehabilitation [14]. It is also important that the tasks performed by the patient are meaningful for the patient and relate to their perceived problems [15].

The GENTLE/S system provides the opportunity for repetitive task oriented movement, a form of therapeutic intervention that has been shown to be of benefit [16,17]. In addition to this it provides the following feedback to the patient to enhance attention and motivation and hence further facilitate motor recovery through brain plasticity:

- Visual Feedback – Realistic and accurate goal oriented 3D environments. This can be anything from a virtual room, a virtual kitchen, museum, to an interactive game, etc.
- Haptic Feedback – Kinaesthetic feedback helps to discriminate physical properties of virtual objects, such as geometry. It can also be used to deliver physical therapy to a human subject using haptic interfaces. In our system it is used to guide the patients arm along a pre-set movement pattern. The amount of force used to bring the arm back to the set path can be varied to suit the individuals needs.
- Auditory feedback – Encouraging words and sounds are played when the user is trying to perform a task, congratulatory words when a task was achieved with success and comforting words when the task wasn't achieved.
- Performance Feedback – Results of previous tasks can be displayed stating the errors committed and the level of help obtained to complete the task.

We hope to be able to foster the patients' trust by developing a sense of friendship and companionship between the patient and the system. A personality can be added to the system by having a character (wizard) that interacts with the patient. Different wizards can be implemented for different personalities. These are defined and assigned to the patient once the therapist has assessed what their interests are. We hope that the wizards will further enhance motivation and attention during this therapy.

3. The System

The current prototype system (Fig. 1) consists of a frame with two chairs, a shoulder support mechanism, a wrist connection mechanism, two embedded computers, a large computer screen with speakers, an exercise table, a keypad and a 3DOF haptic interface arm (Haptic Master). The patient is seated on the chair with their arm positioned in an elbow orthosis suspended from the overhead frame. This is to eliminate the effects of gravity and address the problem of shoulder subluxation. The wrist is placed on a wrist-orthosis connected to the robot arm using a quick release mechanism (Fig. 2).

Figure 1 – GENTLE/S Prototype 1

Initial studies with a group of stroke patients at the Young Stroke Association in Stoke-on-Trent, UK, have encouraged further development and enhancement of Virtual Environments to deliver therapy [18]. *Virtual tasks* consist of a goal oriented computer graphical user interface based on virtual reality visualisation techniques. The therapist, using the task editor, can create a virtual task. The system allows the therapist to create new movement patterns in virtual 3D environments and to define how objects are related to each other and what kind of behaviour they represent to the patient. For instance, one simple activity involves the patient to reach for a can of Pepsi and move it close to a book in the table.

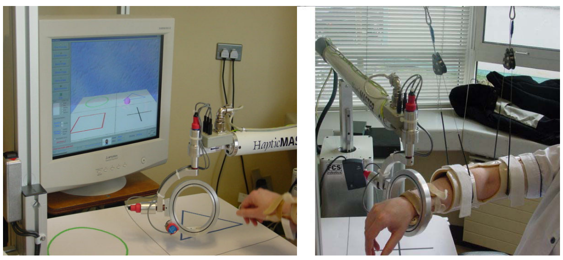


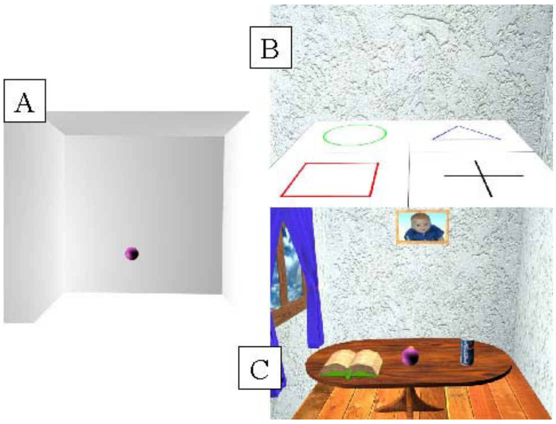
Figure 2 – Robot end-effector and arm orthosis

4. Initial pilot trials

Following ethical and safety approval, the initial pilot trials are ongoing. We have created and used 3 different graphical environments (Fig. 3) for the initial trials:

1. Empty room – A graphically poor environment consisting of white walls, a floor and ceiling, representing the 3D workspace of the system.
2. Real room – An environment that resembles what the patient sees on the table in the real world. The mat with 4 different shapes that is on the table is represented in the 3D graphical environment.
3. Joaquim's room - A high detail 3D environment of a room comprising of a table, several objects (a book, can of Pepsi), portrait of a baby, window, curtains, etc.

Figure 3 – (A) Empty room, (B) Real room,



(C) – Joaquim's room

We have assessed the suitability and usefulness of the three different visual environments, the 2 levels of force feedback and the motivational aspects of the system using a questionnaire survey of patients with stroke using the first prototype in the pilot trials.

4.1 Perception

Several questions were asked to evaluate the patients' ability to identify and correlate his movements in the real world to what is displayed on the screen. This information will help us to design environments that are easy to interact with.

Patients completed a simple 4-point exercise (3D pyramid) in each of the three environments for 2 minutes. Four questions were asked to evaluate their opinion on the environment's look, realism, and ease of use.

4.2 Force feedback

The Kinaesthetic feedback forces were used on 2 different settings: strong (i.e. highly stiff; exerted a strong pull back to the desired path) and weak (i.e. low stiffness; allowed the patient to deviate more from the desired path and exerted a lesser force to bring the limb back to the path).

The patients exercised for three minutes on each setting in environment A (fig. 2 (A)). To evaluate the effectiveness of Force feedback, questions were asked to collect patient's opinion on whether the force feedback helped them to perform the movement, which setting made it easiest to complete the movement and which setting they preferred.

4.3 Motivation

These tests were performed to collect patient's opinion on motivational aspects of the interaction between people with stroke and the haptic interface. We collected information on the total time that they exercised for, whether exercising in the system was more interesting than their normal therapy and how long they thought they could exercise for before it would become boring.

After 10-minute intervals, patients were asked whether they wished to continue with the same exercise, change to another exercise or stop.

5. Results and discussion

The tests described in the previous section were performed by 8 respondents, of which 1 had a Cardio Vascular Accident (CVA) more than one year ago, 3 had a CVA between 3 months and 1 year and the remaining 3 had a CVA less than three months prior to testing. Of these, 6 had left hemiplegia and 2 right hemiplegia, 6 were female and 2 were male. Their ages ranged from 50 to 81 years.

5.1 Perception

Table 1 shows that although most patients found environment C the nicest to look at, 6 of the 8 patients actually enjoyed practising in the mixed environment (B). This suggests that by providing a degree of realism we are correlating what the eye actually sees on the screen with what exist in the real world, which in turn makes the experience more enjoyable for the patient.

On the other hand, the relatively complicated graphical environments were not felt by the patients to be the easiest in which to interpret the required direction of movement from the 3D image.

Question	Environments			
	A	B	C	Undecided
1. Which room look the nicest?	1	3	4	
2. Which room felt more realistic?	0	5	3	
3. In Which room was easiest to know where you had to move next?	3	2	2	1
4. Which room did you enjoy exercising the most?	2	6	0	

Table 1 – Patient answers on perception.

5.2 Force Feedback

For this test it was required that the patient had some level of activity and were exercising in active mode (i.e. the robot did not provide any assistance in the completion of the required movement and provided a velocity dependant resistance to the patients effort).

Four patients completed this section all of whom responded that the force feedback was useful in completing the required movement pattern. Three of the 4 patients preferred the 2nd setting (weak force). They commented that this was because on the strong setting they had to work harder. Although this may be less enjoyable it may actually be of greater therapeutic benefit and it is worth noting that 2 of the 4 patients had a better quality of movement on the strong setting. We therefore conclude that it is important to set the force to accommodate the patients needs.

5.3 Motivation

All of the six patients that completed this section felt that the system helped them to exercise for longer than they normally would in their traditional therapy session. Five of the six felt that therapy on the GENTLE/S system was more interesting than their traditional therapy session.

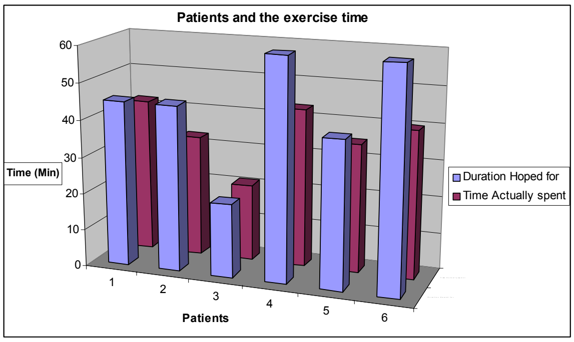


Figure 4 – Exercise time results.

When they were asked, how long they could exercise for before it would become boring; 5 of the 6 patients responded with times that were greater than the time that they had spent exercising (Fig. 4). It is worth noting that 7 of the 8 patients in the pilot trial stopped exercising because of arm fatigue rather than boredom.

6. Future Work

The initial clinical trial, which is currently taking place, involves evaluation of the prototype in terms of design, patient comfort, ergonomics and ease of use by both patient and therapist. Later in the year a full clinical trial will commence, which will evaluate the GENTLE/S system in terms of therapeutic benefit at the levels of impairment, disability and handicap.

Also we are going to look at virtual tasks allowing manipulation of objects and the haptics of manipulation of virtual and real objects in real tasks. At that point we will investigate and analyse the biomechanical data to determine if haptic technology and the development of wizard intelligence will positively contribute towards the advancement of assistive technologies.

7. Conclusion

This paper has presented the initial ideas and concepts for adapting and using dedicated haptic interfaces as part of the rehabilitation process of stroke patients. Our approach is based on the fact that attention and motivation are the keys for recovery.

The initial pilot studies have shown that the majority of the patients were positive towards the use of visual and haptic cues. Some of the results, with emphasis on visual perception, suggested that we would benefit by using augmented (mix) environments and also we would need to manipulate objects on both worlds.

Our force feedback test suggests that a patient might feel less force is more useful, although this does not necessarily means that it is therapeutic. Further investigation is necessary to prove the usefulness of haptic interfaces, especially force feedback.

Also this result allowed us to conclude that the amount of assistive force should be tuned for each individual, otherwise it might create extra impedance.

Finally, as a whole the system has proven to motivate hemiplegic patients to exercise for longer than they normally would in their traditional therapy session.

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