# Creating gesture controlled games for robot-assisted stroke rehabilitation

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#### Structure: 1. Introduction / 2. Methods / 3. Results / 4. Conclusion

## Abstract

Regular training exercises are fundamental to regain functional use of arm and hand control after a stroke. With the SCRIPT system, the patient can practice hand excercising independently at home by playing gesture controlled games using a robotic glove (orthosis). The system could offer prolonged rehabilitation out of the clinic, with low cost treatment. In the first version of the system (Script 1), a set of therapeutic games were developed within the project and tested in formative and summative evaluations. The main findings indicate that motivational aspects play a major role. The main issues detected concerns the challenge for the patients to understand and remember the correct gestures. Following a User Centered Design process, these findings helped to improve the new version of the system (Script 2).

## **1** Introduction

The SCRIPT (Supervised Care and Rehabilitation Involving Personal Tele-robotics) project aims to create a rehabilitation device to be used by stroke patients in their homes for training wrist and hand movements. One goal of the project is to make training more motivating and therefore more effective/efficient. For this purpose, gesture controlled games are used for training, including an orthosis to support and measure the movements.

#### 1.1 Background

Many patients after stroke have impaired arm and hand function, which limits them in performing activities of daily living independently. Intensive and active training is important to regain functional use of the arm and hand after a stroke. Due to high costs and limited availability of health care professionals, intensity and/or dosage of rehabilitation is often limited. Hence, any technical device that can prolong neurorehabilitation out of the clinic, with low cost treatment, plays an important role in the health management systems [1]. One of such applications is rehabilitation robotics, since it can provide more independent, repetitive, task-specific, interactive treatment of the arm with high treatment intensity [2-4]. In order to increase the treatment dosage even more, such a treatment is preferably applied in the home situation, via remote monitoring and supervision [5].

#### **1.2** User Centered Design Process

When following a User Centered Design (UCD) process as described in ISO 9241-210, the needs of the user are in focus, as well as the whole context in which the product

will be used. To gather reliable information, it is advised to include users in the development process. The process consists of iterations of four phases: (1) analyzing the context of use, (2) defining the requirements, (3) concept and creation and (4) evaluation. This feedback will help to improve the system iteratively. The UCD process applied to the Script project is described in chapter 2.4.

#### **1.3** About SCRIPT

The SCRIPT system consists of a user interface (UI) on a touch screen, a set of games for training and an orthosis which supports the patient's movements. The patient's system is remotely connected to a therapist application for supervision. Defined user groups of the Script system are chronic stroke patients with affected hand or arm movements, as well as treating therapists. This paper focuses on the patient user group.

In the project, two versions of protoypes are created and tested: SCRIPT1 includes a passive orthosis [6], while SCRIPT2 works with an active orthosis. This paper mainly describes evaluation of SCRIPT1 and subsequent improvements realized for SCRIPT2.

### 2 Methods

#### 2.1 SCRIPT orthosis

The SCRIPT Passive Orthosis (SPO) is a wrist, hand and finger orthosis that assists individuals after stroke, suffering from impairments caused by spasticity and abnormal synergies. The SPO offsets these undesired torques with passive springs that pull the joints towards extension. The user carries out voluntary muscle activation to perform movements and thus stays actively involved. The SPO is equipped with sensors to measure the joint rotations and applied forces at the joints, which are used to interact with a gaming environment. It also provides information on the user's forearm posture and movements.

#### 2.2 Games

As a part of the SCRIPT project, a set of games for stroke rehabilitation is developed. Three games have been delivered in year one of the project, six in year two and again four will be developed in year three. Feedback on the first set of games was used to improve the concepts of the next set. When creating a game concept several aspects are considered, along with the game idea and the scenario: (1) the goal of the game, (2) which gestures to include from a therapeutical point of view, (3) how many levels are needed and how they differ and (4) how the difficulty is to adapt within one level.

### 2.3 Patient UI

In therapy, suitable games are assigned to the patient by the therapist. There is a game description in the patient UI (game details screen) to explain the game and to help the patient to decide which game to play.

Movement performance is likely to change dramatically between sessions, due to subject's both inter- and intraindividual variability. Shorter, smaller movements can be expected from more severely impaired subjects and the way that one person performs a movement can change due to motor (re)learning. Hence, a calibration phase (calibration screen) was inserted for each of the gestures performed within a game. The subject is asked to perform a few repetitions of the desired movement(s), for a maximum of 30 seconds. Movement duration and amplitude are measured, which provides a way to evaluate subjects' improvement. The calibration procedure also allows fitting the game to the individual skills and needs. The parameters for gesture recognition and game speed are adjusted based on the calibration outcome, so that objects appear on the screen at a position, distance and velocity which makes successful performance neither impossible nor too easy.

## 2.4 UCD in SCRIPT

SCRIPT project follows a UCD process and several studies have been conducted for evaluation of the system, so far mainly for SCRIPT1. The feedback on the UI and the games has been used to improve the SCRIPT2 system.

#### 2.4.1 Formative Evaluation

A set of formative evaluation activities were carried out in order to gather feedback for improvements on the Script1 system. Participatory formative evaluation methods were used, such as cognitive walkthrough and cooperative evaluation [7]. Evaluations were carried out across three clinical sites. Feedback was collected from members of the steering group committees including patients, carers and stroke professionals. In addition, usability issues were identified during evaluations in participants' homes. Six households were visited, where participants and their carers were asked to try out the system by perfoming a series of tasks while also encouraged to think aloud.

#### 2.4.2 Summative Evaluation

Twenty-one subjects (10 males, 11 females) were included in the clinical study. Mean age was 59 years, mean time post stroke was 19 months. The chronic stroke patients used the SCRIPT1 system for training at home, for six weeks. All subjects trained independently, and were remotely supervised, offline, by a healthcare professional. The feasibility of the SCRIPT1 system (including the games, motivational UI and orthosis) was assessed, to investigate validity and usefulness of the system. Evaluation of feasibility involved compliance in terms of actual use (training duration in minutes), usability measured by the System Usability Scale (SUS) [8], and user acceptance of the total SCRIPT1 system by a semi-structured interview.

#### 2.4.3 Usability Test (SCRIPT2)

Results of formative and summative evaluation of SCRIPT1 were used to improve the next version of the system, SCRIPT2. Before the next clinical study, a usability test was planned and conducted to prove updated concepts. The patient UI for SCRIPT2 was evaluated in a usability test (UT) with three patients. The participants were all male and the time of the stroke was between eight and 22 months ago. The tests focused on the UI, and the use of the orthosis as well as the control of the games was not included in the test set-up. The UI was presented on a 21.5" touch screen.

First half of the test sessions was spent to find out basal needs of the patients when interacting with the system, by using the Valence method [9]. Patients were allowed to interact freely with the UI and were instructed to set positive and negative markers whenever they liked or disliked something they were experiencing. The markers were then reviewed and discussed together with the patient. Afterwards, the patients performed specific tasks like running the calibration process. Before the closing interview the games were shown to the patient, and the gestures used to control the games were explained.

## 3 **Results**

### 3.1 Evaluation Results

During evaluation, feedback was given concerning the games and parts of the UI which were directly associated with the games (e.g. the calibration screens and game details screen). The results implied the following conclusions:

Games

- Patients had problems to understand and remember what gestures to perform in some situations.
- It is important to clearly indicate when a gesture is successfully performed and scores are earned.

- The orientation of grasps must relate to the orientation of the corresponding objects, e.g. if a banana is shown horizontally the grasp has to be performed horizontally.
- Clear feedback in the games is a must, e.g. visual or acoustical hints to indicate when an object is selectable, or was successfully handled. This is also a matter of motivation.
- It has to be directly visible how to pause or end a game. Touching the screen to pause or stop the game was not clear enough.
- One of the games was perceived as monotonous, because of too little variation. On the other hand, games must not require gestures that are too difficult to perform.

Patient UI

• The gestures presented on the game details screen were not clear to the patients, e.g. the combined gesture visualization for flexion and extension of the wrist.

Calibration

• The calibration process was experienced as too long and it was not clear when to start performing a certain gesture. Some patients did not understand the word "calibration".

Technical issues

• Patients were annoyed by poor controls of the movements in some of the games, e.g. when the game did not react on patients' movements.

Main positive feedback about games as assessed by the semi-structured interview of the summative evaluation:

- The scoring element. Most patients liked to improve their previous earned scores, which motivated them to practice more and more.
- The variation in difficulty, like the automatic speed correction of the obstacles.
- The variation in activities available in one of the games, with different and more arm/hand movements in higher categories available. This keeps the game challenging and motivating.

During the summative evaluation, the average training duration was concluded to  $105 (\pm 66)$  minutes per week, which comes down to about 15 minutes of self-administered practice at home per day. However, the individual training duration per subject varied considerably, ranging from 13 up to 284 minutes per week.

The group average SUS score was 69%, indicating that usability of the SCRIPT1 system is promising with a good chance of acceptance in the field. Individually, three subjects scored 'usability difficulties in the field' (SUS <50%), whereas ten subjects scored the SCRIPT1 system as promising or high acceptabilitity (SUS >70%) [10].

#### 3.1.1 Usability Test results (SCRIPT2)

Above all, patients want to feel competent while using SCRIPT. In this context especially the following needs were identified: to complete tasks independently, get along unaided and be in control. Patients wished for physical activity as well as learning and trying new things (need: curiosity) and having fun. More positive than negative markers were set, which indicates that the patients' needs are mainly fulfilled. In the tasks part of the test, patients had difficulties conducting the calibration process: Patients performed the correct gestures, but did not know when exactly they had to perform the gesture. In the screens showed, the corresponding game actions were described in the calibration screen, but test results showed that this still is not enough to remember the gestures. Confronted with the games, two of the patients mentioned a wish for games that also challenge the brain.

#### **3.2** Implications on the games

Analyzing the results of the evaluations, the following aspects are taken into consideration when developing new games for SCRIPT:

- Show images of the requested gestures as hints in the games. With this solution, the patient does not have to remember the correct gesture and can concentrate on performing the movement (see image 1).
- Gestures of the patient must be recognized reliably by the system. Any technical issues or bugs leads to frustration and must be avoided.
- Carefully prove that objects in the game correlate with the real grasping gestures, e.g. grasping a stick with a cylindrical grasp. Orientation of the object needs to correspond with the orientation of the gesture.
- To support motivation, always display the scores and motivational messages at the same place consistently throughout all games.
- Include a visible Pause button in all games.
- Give clear visual and/or acoustic feedback when an object is selected or when an action was performed correctly.
- In the next generation of the orthosis, the interface to the fingers will be improved to apply pure torques and to get a higher measurement accuracy. This should further improve the control the users have during the games.



Image 1 Fruit picker game (SCRIPT2), displaying the requested gesture

### 3.3 Improvements on patient UI

#### 3.3.1 Game details screen

The issue for the patient to remember what gestures to use in a game, also affects the game details screens. The description of the game and its gestures are now displayed more clearly, the game icon has been replaced with a screenshot from the game and gesture visualization has been simplified, e.g. by splitting wrist flexion/extension into two separate gestures, when used separately for different acitivies in the game (see image 2 and 3).



Image 2 Game details screen for SCRIPT1



Image 3 Updated game details screen for SCRIPT2

#### 3.3.2 Calibration screen

Based on the evaluations and the usability test, the calibration screen was improved with a a step indicator, to clarify that calibration is a process of several steps. The wording was changed from the technical term "calibration" to "adjustment" and a description of the corresponding game gestures was added. The visualization of the calibration gesture will also be animated, to clearly indicate to the patient when it is time to perform the gesture and how to perform it.

## 4 Conclusion

In the SCRIPT project, a system targeted for Stroke patients to pratice hand excercising at home with the aid of gesture controlled games has been developed and evaluated. Training duration and SUS scores where promising and further work will aim to improve these aspects further. Based on the results on the evaluations and the usability test, improvements have been carried out for Script2 regarding the UI, the orthosis and the existing games, and in addition six new games have been developed. The whole system will again be tested by patients at home in a second summative evaluation, using an active orthosis this time.

A new set of games will be developed for SCRIPT in year three of the project. During the concept phase and development, the evaluation feedback received so far will again be considered. Aspects of learning and motivation will be taken into account, as well as the request to include more challenges for the brain, in addition to the training of hand and arm movements.

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