Gesture Based Games in Stroke Rehabilitation

Challenges and Lessons Learned

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Abstract

Main goal of the research project SCRIPT is to develop a motivating system for stroke patients which they can use independently at home to train hand and wrist movements. This involves playing interactive games controlled by a robotic glove. This publication describes the development of the games and particularly the challenges of developing a gesture controlled interface for such a specific user group. Stroke patients have limited control and range of motion in the affected hand and the primary aim of the games is to encourage repetition of therapeutic movements. Games will be presented, as well as concept ideas for future games. Lessons Learned will be illustrated, e.g. how to include the important gestures logically in a game concept. Additionally, we will discuss what appears to influence the motivation to play, e.g. visible feedback in terms of scores.

Keywords

therapeutic games, gestures, stroke rehabilitation, motivation, range of motion

1 Introduction

The SCRIPT (Supervised Care and Rehabilitation Involving Personal Tele-robotics) project aims to create a tele-rehabilitation device to be used by stroke patients in their homes for training wrist and hand movements. Training is done by playing games controlled by gestures and patients wear a robotic glove to support and measure the movements.

1.1 Background on Stroke

Stroke frequently leads to impairments on one side of the body (hemiplegia) which can affect use of the upper limb and hand (NSA, 2014; Somerfield et al., 2004). Evidence demonstrates that only 50% of those with upper limb paresis will regain useful function (Broeks et al., 1999). This makes it difficult to perform even the easiest activities in daily living, like drinking from a cup and eating with a knife and fork. To improve future functional capacity and ability it is essential to exercise the arm and hand regularly (Krakauer, 2005; Schaechter, 2004; Oujamaa et al., 2009). Rehabilitation in the form of intensive repetitive task specific exercise is essential if functional abilities and independence are to be regained following stroke (Miltner et al., 1999; Rossini et al., 2003). The SCRIPT system has been designed to enable chronic stroke patients with affected hand or arm movements to perform this training independently at home, supervised by a therapist at a distance. This is based on the hypothesis that an enriched and engaging environment will motivate patients towards recovery (Carr et al., 1987; Maclean et al., 2000) and that performance of tasks may improve with repetitions (Karni et al., 1998). Availability of a system at home where access to rehabilitation is unrestricted is a further chance to allow repetitive training of arm and hand functions, thus contributing to patients recovery. Within this training routine, typical movements involving the arm, hand and wrist that are used in active daily living, include: reaching with the arm (forwards, backwards, left, right, up and down); turning arm so the palm faces up or down (pronation/supination); specialized grasps for different shaped objects; and releasing grasped objects.

1.2 About the SCRIPT Project

The SCRIPT system consists of two parts: One system for stroke patients and one application for the supervising therapist, both remotely connected. This publication will only focus on the system for patients. It consists of a touch screen with a simple communication and feedback interface, a robotic glove to support the hand/wrist movements (see Figure 1) and gesture controlled games for the training of the hand and wrist.

Figure 1: First prototype of robotic glove, worn by a healthy subject

2 Methods

2.1 UCD Process

The SCRIPT project makes use of a mix of health services and UCD methods for data gathering. These methods include for example focus groups, individual qualitative interviews and use of technology biographies. Both functional and patient-reported outcome measures and participatory evaluation methods are applied. This mix of methods reflects the different disciplines involved in the project, like technical partners, researchers with clinical background and usability professionals.

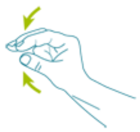
During the first two years of the project, we gathered various forms of feedback on the first prototype, amongst others feedback from clinical researchers and observation of users. Additionally, the prototype has been tested in 24 home settings with people with stroke over a period of six weeks (clinical study). The clinical study included requests for a weekly report of usability problems by the participants as well as researchers' observation of how the users manage to use the system; their successes and challenges. In addition, semi-structured one-to-one interviews were conducted as part of this evaluation to explore user experiences and views at the end of the testing period. Interviews were conducted with fifteen participants. The gathered feedback concerns the whole experience with the system, like the UI, the robotic glove and the games. This publication only focuses on the feedback concerning the games and the gestures needed to play the games.

During the further proceeding of the project feedback was gathered in preparation for the next clinical study with a second prototype. A steering group meeting was conducted which involved a small group of end users and their carers (4 participants), health care professionals (3 participants) and researchers (4 participants). This involved both viewing and testing four prototype games.

2.2 Gestures

When selecting the gestures to be used in the games, different aspects have to be considered. On the one hand, gestures must have a therapeutic goal and help patients to improve movements needed to perform activities of daily living. On the other hand, only those gestures can be included that can be recognized and measured reliably by the system. Table 1 below shows which gestures have been available through the system. Cylindrical, palmar and lateral grasp have not been available for the first games due to technical limitations.

Table 1: Overview of gestures available for the SCRIPT system

Gesture	Visualization	Gesture	Visualization
Wrist flexion		Wrist extension	
Move arm left and right		Move hand/arm forward/backward	
Grasping (open and close hand)		Cylindrical grasp (like when holding a bottle)	
Palmar/Tripod grasp (like when picking up something small and light like a snail/marble)		Lateral grasp (like when holding a key to lock a door)	

2.3 Adjustment of the System to the Patient

Stroke restricts the range of movements that patients can perform. Following a severe stroke, a patient may have only a few degrees of rotation in the joints on their effected side, whereas a less severely affected patient will have more movement in the same joints. To ensure appropriate reactions of the games, the system has to learn the characteristics of the patients movements in a calibration process. (Basteris et al., 2013) Therefore, before playing a game, the SCRIPT system guides the user through a series of training steps, where it prompts the patient to perform certain gestures used in the game.

2.4 Games

To allow patients to select different games according to their own preferences and therapists recommendation, a number of games will be developed during the SCRIPT project: eight games have already been implemented/rolled out and tested so far, and three more games will be created until the end of the project. Following a UCD process cycle, conclusions from the previous evaluations will influence the development of the new games.

When creating a new game for SCRIPT, the first task is to ask technical partners about the current capabilities of the robotic glove prototype and the control software. We especially need to know which gestures can be recognized or assisted/resisted by the system. This is followed by a brainstorming session on game concepts. The first ideas are sketched and explained to clinical partners who consider the therapeutic purpose and value in this respect. Technical partners give feedback on the feasibility of the concept.

Every game developed has to follow certain objectives: use therapeutically beneficial gestures, have an easily understandable game concept and motivate the patient to train more and regularly. As patients have different degrees of limitations it is essential to offer games with various challenges. Therefore, games can have different levels of difficulty or/and include different gestures. Suitable games and levels are then assigned to the patient by the therapist. Following, some of the created and tested games will be described in more detail.

2.4.1 Game: Seashell

The goal of the Seashell game (see figure 2) is for the clam to eat as many fishes as possible. The patient controls the seashell. To “awake” the shell the patient must move the wrist up and hold it in this position (wrist extension). Fishes are eaten when performing a grasping movement at the right point in time. In daily living, hand opening and closing is most often done while the wrist is not flexed, while typical stroke patients suffer from abnormal synergies, where hand and wrist flexion are unusually tied together. So if a patient closes the hand, his wrist automatically flexes without his control. Playing the game encourages exercising the wrist and hand opening and closing at the same time while providing a chance to control hand flexion when the wrist is fully extended.

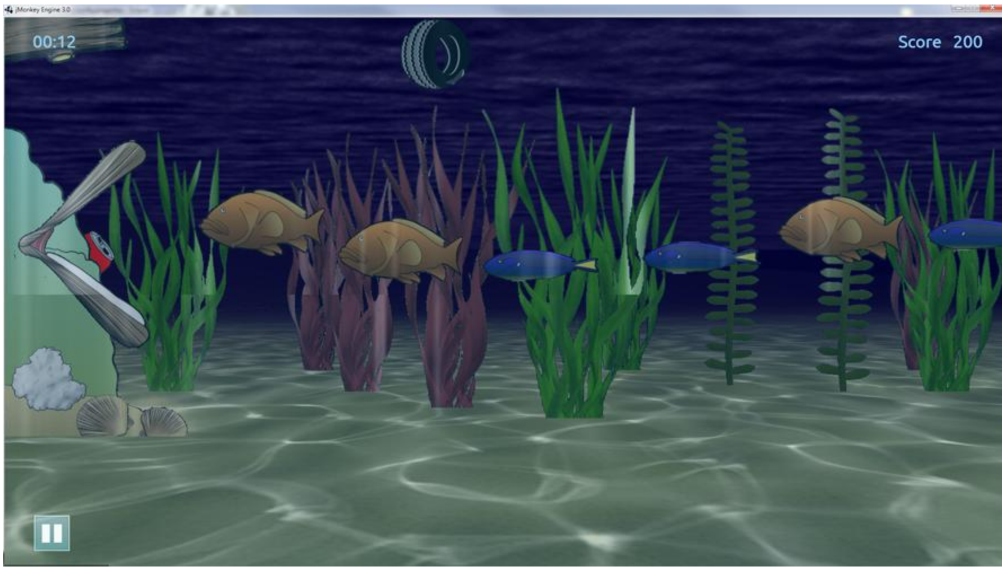


Figure 2: Screenshot of the Seashell game

2.4.2 Game: Fruit Picker

For a severely affected stroke patient, just opening and closing the hand is a significant challenge. As the patient makes recovery gains, however, therapy for finer control of grasping actions must be introduced. Therefore the Fruit Picker game (see figure 3) includes different grasping movements. The goal of this game is to collect a defined amount of fruit in the baskets within a set time frame. On the side of the screen, three types of fruit continue to fall. The patient has to grasp the respective fruits and drop them into the correct basket. Depending on the kind of fruit, different grasps are required; a cylindrical grasp for the banana, a lateral grasp for the piece of water melon and a palmar/tripod grasp for the cherry.

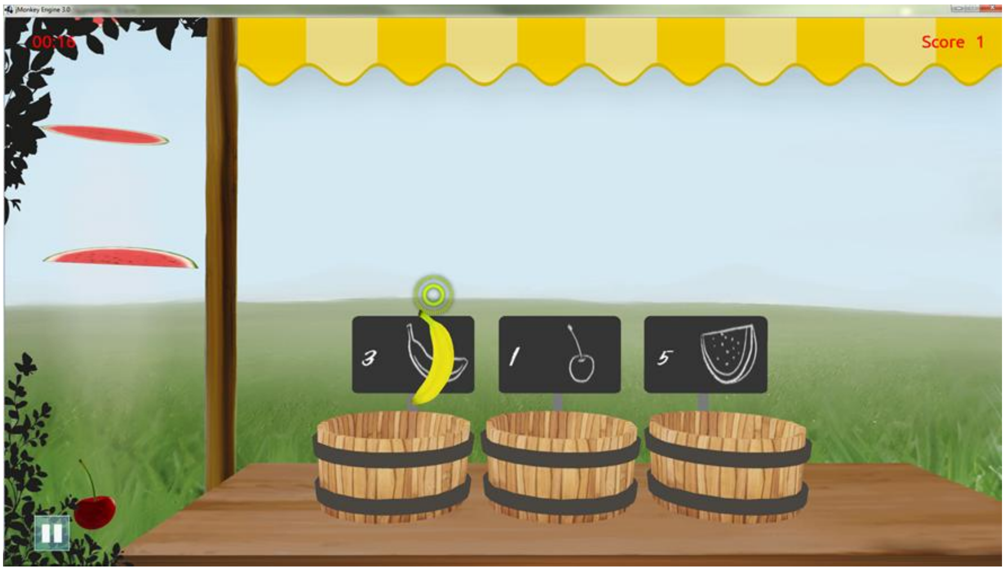


Figure 3: Screenshot of the Fruit Picker game

3 Results

3.1 Challenges and Problems with using Gestures for Game Control

The results of the evaluations provided important insights about the games and how to potentially improve them. The overarching finding was that games divert the patients from the mundane and otherwise rather boring task of exercising and are liked.

However, patients can become frustrated when a game is too difficult with this being a feature of individual capabilities and limitations. For example some patients were not able to play the Seashell game properly as they had difficulty with maintaining their hand in the basic position with the wrist up. The importance of a growing level of difficulty proved true.

Especially the first level of the game has to be very easy to be achievable by most patients. As fine motor skills improve, more gestures can be added in higher levels.

In general, it is very difficult to find objects that meet the required gestures for real life functionality and fit into the game concept. This was specifically challenging when using different kinds of grasps, like cylindrical, lateral and palmar/tripod grasp. For example we experienced problems locating appropriate fruits for the three types of grasps in the Fruit Picker game. The grasps themselves are part of a repository of grasps performed in daily life. However, finding a subset that can be performed within a game context is rather difficult as it also depends on device sensing capabilities, and its wear. For example, given the patient has to place his fingers into plastic finger caps of the robotic glove, those grasps that rely on fine and precise finger coordination are more difficult to realize.

We found that it is crucial for the understanding of the game and therapeutic playing that objects shown in the game correspond to the requested gestures as far as possible. The orientation of the object in the game also influences the orientation of the performed gesture and should correlate to it.

Patients reported finding it difficult to understand and remember what gestures they have to perform in the game. Despite a detailed game description and the calibration session before it was hard for them to remember, which can be a symptom of the brain damage caused by the stroke. For further games, we therefore decided to show a visualization of the correct gesture within the games, as soon as the patient is hovering his hand over an editable object. In this way, patients do not need to remember the correct gestures and can focus on performing them correctly.

3.2 Motivating Factors in Games

To give patients feedback and motivation, bar charts have been included in the patient UI from the beginning: In this way, the patient can view his progress concerning game scores and training duration, e.g. after a training session. In the evaluation of the first prototype, we found out that also direct feedback within the game is important for motivation, e.g. by seeing earned scores grow, hearing a sound which corresponded with a successful action or getting other visual feedback. For example, in the Seashell game, patients complained about missing feedback when a fish is eaten. The fish only disappeared behind the rock, while patients expected to see a fishbone or something similar. In common with what we know from comparable games, various kinds of feedback are required depending upon personal preferences. Based on the evaluations of feedback and motivation, the following conclusions were drawn:

- The gaming must operate reliably within a technology system that is reliable overall.
- Scoring needs to be accurate, that means comprehensible and predictable.
- Training scores should be consistently visible, as they can motivate the user to improve during playing.
- A set of different and appropriate motivational messages are needed.

As with all gaming systems, the level of difficulty also strongly influences the motivation to play the game. Depending upon the abilities of a patient, the same game might be either too challenging or too boring. For this reason, there is a need to develop different levels of difficulty for a game. We use a taxonomical classification (Gentile, 1978) to progress through different difficulty levels as patients make progress.

3.3 New Game Concepts

For the final prototype we are currently working on concepts for new games which will incorporate all issues learnt so far. There might be technical limitations that will not allow us to implement the concepts according to the original ideas. Testing these with the patients will then highlight other requirements which will be considered through the next design stages, and the final tests rely on actual use of these games within the rehabilitation program.

3.3.1 Game Concept: Cross the Bridge

The goal of the first game concept for the final year named ‘Cross the Bridge’ (see figure 4) is to balance a bridge by putting objects on the other side. If the bridge is balanced correctly, it is possible to cross. Here we are carefully picking logical objects for the three types of grasp (cylindrical, palmar, and lateral). For example we use a snail for the palmar grasp. To give an additional visual feedback in case of success we plan to show a small animal crossing the bridge and reach the other side.

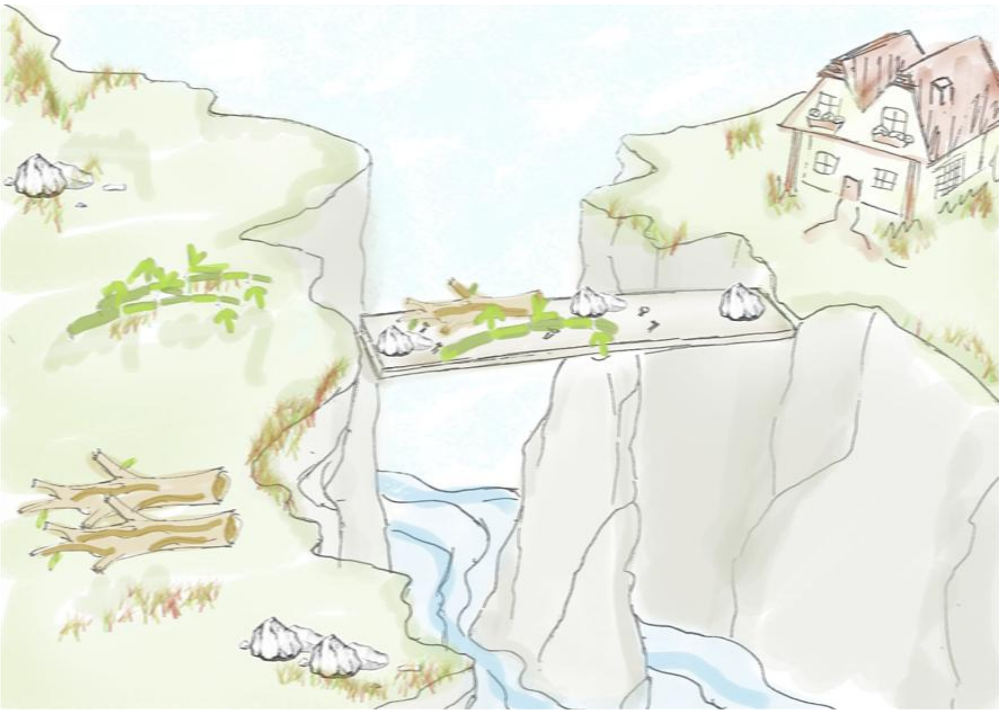


Figure 4: Concept sketch of the Cross the Bridge game

3.3.2 Game Concept: Map game

The second game for the final prototype, the Map game (see figure 5) is a puzzle game. Here a map of a continent is presented to the user with the goal to place the country puzzle pieces in the correct places. Here we include brain challenge elements, taking into account expressed desires by participants to also train their cognitive abilities. We adapted the concept to avoid up/down movements of the arm, as this movement may cause painful shoulder strain. Instead, we changed the angle of the map to allow for a forward/backward movement.

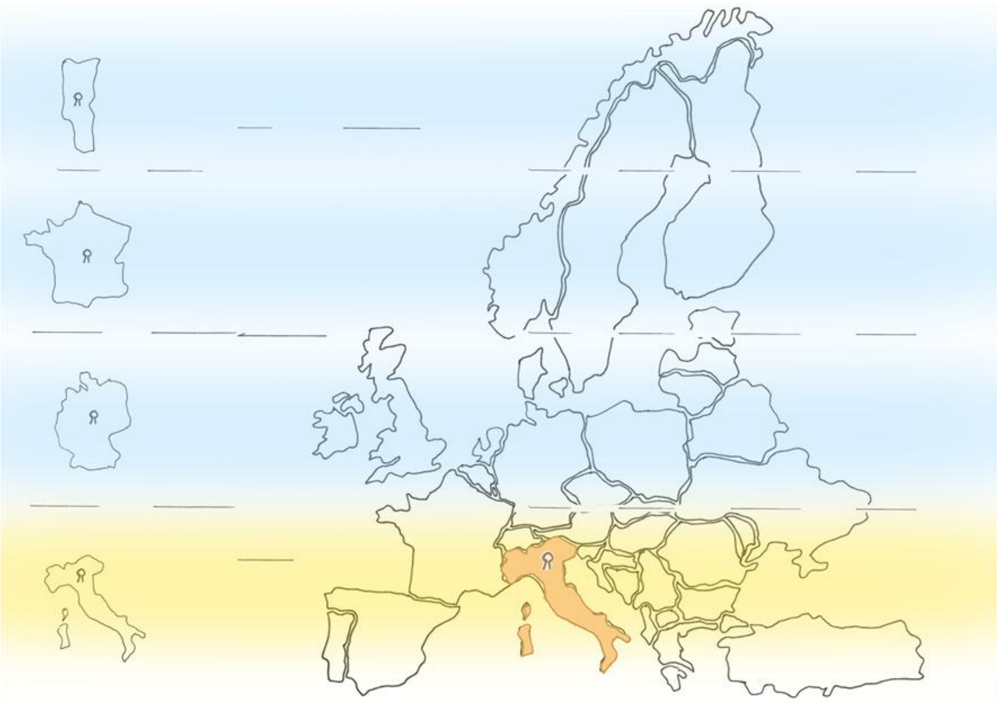


Figure 5: Concept sketch of the Map game

4 Conclusion

In the next project phase a second prototype is planned to be tested in three countries in another clinical study.

Although SCRIPT involves one specific user group, at least some of our findings are likely to be valid for projects where games are used to facilitate frequent interaction and/or in-air gestures of the upper body. Findings related to motivation, personal feedback and gradual increase of game complexity are amongst others likely to apply to a whole range of functional exercises that can influence motor-recovery and affect plastic changes in the brain, or encourage neural activity in an injured limb.

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7 Authors

Franziska Schätzlein works as a Senior Interaction Designer for User Interface Design GmbH (UID). She mainly creates interaction concepts for all kinds of interactive products, e.g. for enterprise software, industrial machines and within research projects in the field of AAL. Additionally, she conducts user research studies. She studied Information Design at the Hochschule der Medien (HdM) and gained the Friedrich-Wiedenmann-Preis as best graduate of the year. The award also included her bachelor thesis where she conducted a usability test with seniors in a virtual environment. Together with Ellinor Johansson, Franziska Schätzlein is responsible for all questions concerning UI concept, games concepts and usability in the SCRIPT project.

Ellinor Johansson works as a User Experience Consultant for User Interface Design GmbH (UID). She conducts user research studies and is an expert for usability testing, expert reviews and context interviews. For UID, she turns customer and user requirements into modern interaction concepts. Ellinor Johansson studied Cognitive Science at Linköping University in Sweden and graduated with a Master of Science.

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Nasrin is an interdisciplinary researcher based in the School of Health and Related Research, University of Sheffield, UK. She is a physiotherapist by background. She was awarded her PhD in Patient-reported outcome measures from Sheffield Hallam University in 2007. Following four years post-doctoral experience in the area of stroke self-management, she has been involved as co-investigator in a project examining the potential of home-based technology for stroke rehabilitation. She has extensive experience of qualitative research methods, experience-centred approaches, technology design, development and evaluation. She employs Participatory and Complex evaluation methods for her evaluation research. Nasrin is an associate member of the UK Higher Education Academy (HEA) with experience of teaching Qualitative research methods, and Evaluation methods to Master students. She has developed a short course and a Master module for evaluating programmes, technology and other complex interventions.

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Naila Rahman holds an MSc in Advanced Computing (1995) and a PhD in Computer Science (2002) from King's College London, UK. Her main area of research has been algorithm engineering and she is currently a postdoctoral researcher at University of Hertfordshire, UK within the EU project SCRIPT.

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