Motiv’Handed, a New Gamified Approach for Home-Based Hand Rehabilitation for Post-stroke Hemiparetic Patients

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Abstract. This document summarizes a master thesis project trying to bring a new solution to hemiplegia rehabilitation, one of the numerous consequences of strokes. A hemiplegic patient observes paralysis on one side of their body, and as so, loses autonomy and their quality of life decreases. In this study, we decided to only focus on the hand rehabilitation aspect. However, there is a clear tendency in stroke patients to stop training regularly when returning home from the hospital and the first part of their rehabilitation is over. They often experience demotivation, having the feeling that they will never get back to a fully autonomous person ever again and tend to put their training aside, especially when they do not see clear and visible results anymore. This is also due to the supervised training becoming sparser. All of this results in patients stagnating or even worse, regressing. Thus, we decided to offer a motivating solution for hand rehabilitation at home through gamification.

Keywords: Stroke · Hand · VR rehabilitation · Gamification

1 Introduction

According to the World Health Organization, 15 million people suffer strokes worldwide each year which can sometimes cause death. Survivors are left with neurological and cognitive issues. Ninety percent of the surviving victims experience some degree of paralysis [1]. As to regain mobility and voluntary movement, they need a continued rehabilitation and therapy following the stroke where repetition is key [2].

This paper aims at explaining our work in providing a home-based hand rehabilitation device for hemiparetic patients. We will first go through the research phase that led us to our concept decision, from studying the stroke condition and the rehabilitation process, to what has already been done in the post-stroke hand rehabilitation field. Then we will explain what our concept consists in, finishing with the complete description of the physical and virtual prototype, looking at all the challenges we encountered and all the solutions we found.

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2 State of the Art

We looked for all types of rehabilitation devices for the upper limb implementing technological assets, as exoskeletons, clinical devices, and innovative products. We did not include the devices like the elastic bands, balls, cubes, games, etc., that can be used in any type of rehabilitations. Some of the considered products are on the market, others are just research projects, or concepts. We will here present only the devices that inspired us. For a more comprehensive state of the art, we invite you to read the two following master thesis [3, 4].

After going over the different kinds of products that we found, the ones that seemed the most relevant were:

- Saebo Rejoyce: A workstation with an 3-axis arm and 6 different types of grips working with a graphic interface for 2D games. Allows movements in every direction while grip training. It aims at working on everyday life movements.
- Saebo VR devices: A hand tracking device allowing the patients to control a game with their hands. No intermediary device is necessary.
- WIM [5] and Fit Mi from Flint Rehab devices: Both are small, simple and innovative devices that take a different approach regarding rehabilitation, using a gamified approach.
- Bimeo Pro from Kinestica: A device is a physical interface between the patient and a 2D game, using the valid side to help the disabled one.
- Project of F. Carneiro, R. Tavares, J. Rodrigues and P. Abreu [6]: A device that interacts with VR. In their case, they are showing the deformation and the motion of the object in the VR environment.

From all the products that we have reviewed, it appears that there recently is a clear trend for training’s gamification. Most products come with a graphical interface or 2D games trying to enhance the patients’ rehabilitation experience. However, a lot of them look outdated which is not really appealing. Given the result of our study, we decided to follow this direction and develop a product that allows gamified training.

3 User Analysis

3.1 Users

Our users are patients that were victims of a stroke and suffer from hemiplegia or hemiparesis and the medical team that is following them. In our case, we focus on patients, who experienced hand paralysis and already regained some hand mobility and are relieved from spasticity. It corresponds to the patient that were just sent home after the end of their rehabilitation in hospital and/or clinic. Patients tend then to stop training as frequently as they were, because the frequency of their supervised session is decreasing. It sometimes implies stagnation in their rehabilitation, but it can also cause the regression of their mobility gains.

Thus, the aim of our product is to motivate the patients to regularly train at home thanks to a device they can use by themselves.
Moreover, since this product will be used in a medical context, the training and the device will have to be adapted to each patient individually. Our secondary user, the medical team, will have to take care of it.

3.2 Users Study

To know a little bit more about our users we decided to create some questionnaires in different languages (italian, french, english) that we distributed on Facebook pages and to therapists and stroke survivors among our entourage. Unfortunately, the outcome of those questionnaires is quite irrelevant since we did not get as much engagement as we wish we would have. However, by going to the Villa Beretta clinic, witnessing exercise sessions, and interviewing patients and therapists, we learned that they are willing to do any exercises as long as they can see tangible results.

In addition, we learned that some patients that had the possibility to go home, had to come twice or three times a week for training sessions of two hours to a half day. It requires time and imposes a rigid organization. Moreover, it obliges the patient to train also at home to continue to keep progressing quickly.

Furthermore, we noticed that the exercises were really repetitive, and the machines were big and expensive. We look for alternative solutions focused on home training on the internet. Various tutorials were stressing out the importance of making progress as obvious as possible thanks to simple tricks. The offered exercises were still really repetitive.

Finally, from our personal experience and the experience of our relatives, we found out that, doing rehabilitation exercises everyday was almost the same as doing physical preparation (sport). In both cases the most difficult part is to stay motivated.

3.3 The Rehabilitation Process and Repetitive Exercises

The rehabilitation process consists in going through numerous repetitions of the same exercise in order to trigger the brain functional reorganization process. Repeating the same exercises can get boring very quickly, which explains the current trend of gamified training. As we saw in the state of the art, gamification consists in the use of 2D or 3D games on a flat screen.

We thought about going further by using a Virtual Reality (VR) game for hand rehabilitation, since it would completely immerse the users into the task they are performing. Virtual reality being a fairly new technology, it is not yet so widespread but it sure will become a standard in the near future. A review of different VR systems for stroke rehabilitation [7] indeed revealed that these systems were useful and recommended for rehabilitation. Then it comforts us in using a VR solution for our product. By VR we mean a 3D game in which the user is immersed in thanks to a VR headset.
4 The Product: Motiv’Handed

4.1 Concept

Our concept is to create a modular, compact and adaptive device which would focus on ADL-based exercises while being unobtrusive in order to motivate the user to train in any circumstances. It then requires having a discrete appearance, not looking like a medical object to avoid shame or any idea of this nature. The idea is to break down as many barriers as we can that can go in the way of sticking to a regular training schedule. It is a hybrid product, which can be used with or without a Virtual Reality Headset. Finally, it is a 3D-printed device, which allows it to be printed with different dimensions, thus it is possible to adapt it to best fit any patient’s hand size.

We chose to reproduce with our device Activities of Daily Living, thus any progress with the product would be directly applicable to real life circumstances. This seemed like the most motivating solution for patients.

The object as standalone will consist in different grips assembled on a single object. You can visualize them on Fig. 1 that shows the various motions that can be done with the object. With this arrangement we are trying to cover as many grips as a user can encounter and must deal with daily.

4.2 Design

Shape. In order to fill in the requirement for it to be unobtrusive, we decided to go for a bottle-shaped object that would fit in any environment. It is important for us that the users would not be ashamed of bringing it with them outside. As each single patient have a different hand size, we made the device adaptative. A parametric 3D model based on a single sketch allows the therapist to change its dimensions thanks to two inputs: the patient’s hand length and width.

Technical Solutions. In order to be able to track the patients’ training and be able to interact with our video game we had to use different components:

- Potentiometers and rotary encoders to monitor which rotational grip is being actuated,
- An electronic montage using a Velostat material sheet to monitor pressure applied on the power grip.
- An Arduino board, a microcontroller, with an integrated Bluetooth low energy module and IMU sensor,
- A battery, for a portable and autonomous device.

**Manufacturing Process and Material.** To be able to make each product with a customized size, we needed to use a process that allowed it. We decided to go for 3D printing. Indeed, nowadays 3D printers are becoming more and more accessible, lowering the production cost, especially for objects that must be produced in small series as in our case. Regarding the material, among the two most common materials used in 3D printing we decided to use PLA, which is cheap, comes in a lot of colors, is less toxic than ABS, and offers sufficient mechanical properties.

### 4.3 Device

After making sure our 3D model was feasible and shock resistant, we decided to print it ourselves using a Fused Deposition Modeling printer. It contains 19 parts to print which takes up to 60 h. To this, needs to be added the post-processing and assembly time. By summing all up, building a complete device can take one week and a half of work for a single person with just one printer at disposal.

### 4.4 Use

As said before the product comes with a VR game but is however usable with or without VR. Indeed, we did not want to force people to have to put a 3D headset to use the device. In addition, it really brings meaning to the idea of a portable device that the patients can bring with them during their trips. In this way they can maintain a high training frequency wherever they might go.

To use the device with VR, the patients need a VR headset and a free desk in front of a chair. Thus, it will be used mostly at home or in a clinic. On the contrary, the device as a stand-alone product can be used everywhere, just by connecting it to the corresponding app and doing the exercises given by the therapists (Fig. 2).

![Fig. 2. Use cases and real prototype/rendering comparison.](image-url)
5 The App

5.1 Companion App

The app (not entirely implemented, only graphics and logic of the app were realized) will connect the therapists to their patients and allow them to monitor from their application their patient’s progress. They will be able to change their patient’s program remotely based on their performance, communicate with them or recommend a new appointment in case, for example, adjustments need to be done with the device.

5.2 Unity App

Our unity application aims at motivating the patients to exercise regularly by providing a pseudo realistic environment while gamifying the tasks to execute. Its second goal is to help the patient in getting a difficulty level that suits them and monitors their progress in order to provide adequate exercises. Moreover, it aims at providing for the lack of contextual setting that the patients may feel when using the regular app program.

Interaction Modes. The interactions within our game has been thought to always revolve around hand training. There are then two modes of interaction:

- Direct interaction: without the use of our device, hand tracking and interaction with the virtual environment is ensured by the Leap Motion. It is a very natural and seamless interaction. There, we decided to use movements that were not actually among the movement list that the device allowed to perform, but are still often practiced during rehabilitation, like pinching and pointing.
- Interaction through our device: For actions representing an ADL task, the interaction will be performed using a specific part of the device. The part that the user will have to use will be indicated in real time with specific icons.

User Interface. In Virtual Reality, the environment evolves with where the user is looking at. Which means that the UI cannot be static in the environment. Therefore, we decided to use a Leap Motion feature that sticks a menu with interactive buttons to the user’s palm. One of them allows the user to switch between motion mode and free interaction mode, the second brings the player back to the main menu, to save or quit the game. The other UI element of the game is an interactive white crosshair displayed at exact center of the user’s view. It becomes green when the player can interact with an object of the game.

Player Movement. For our user we decided to allow two kinds of motion: translation of the player forward and backward, and rotation of the camera around the player. Both are performed thanks to given gestures tracked and recognized by the Leap Motion. To translate the users should point forward with their index or backward with their thumb. To rotate the camera the players should perform a pinch with each hand, positioned one next to another. Then, if they want to rotate right, they just draw their right hand towards the right, and vice versa (Fig. 3).
Presentation of the Game. Our game is a mix between a simulation game and a casual game. It is based on the popular principle of the Escape Game. The user is locked inside a series of rooms and must reach the final one to earn specific objects/points.

In order to access the next room, the users must solve puzzles in a specific sequence that will allow them to unlock the door to the next room. Those puzzles will require the user to use their devices to interact with the game and then solve them.

An Example of a Puzzle: The First One in the Game. At the beginning of the game you need to power some knobs in order to change the color of four cubes to match the ones above the door (Fig. 4).

The repetitive aspect of the training is achieved in two ways: by increasing the number of puzzles to solve or by increasing the number of motions per puzzle.

6 Experience on People with no Disability

We had the opportunity to test our device on some people with no disability, including ourselves. We feared we would lose the device’s position between two interactions, as the eyes are covered by the headset and the device is not visible in the game. Instead we notice that we quickly find it and it is not an issue.

The physical device was working but required fine tuning to insure a more stable and durable connection to the microprocessor. Regarding the game prototype, it was necessary to dimension it better. The player would feel small inside our environment. Furthermore, the translation triggers needed better tunings. In this state, it was not conceivable to test it with a stroke patient. Due to a lack of time we did not continue the project.
7 Conclusion

Developing a home-based rehabilitation device brings a lot of advantages to the patients, who can thus train in a familiar environment when it is the most convenient for them. Gamifying it gives the users an additional motivation to train. But Motiv’Handed is more than just a product offering a home-based gamified rehabilitation training. Indeed, it differentiates itself from the other products on the market, thanks to the following characteristics:

• its portability: the stroke survivors do not need any more to stay at home for training but can also go outside to enjoy fresh air or bring Motiv’Handed with them on weekend or vacation, never breaking their training routine
• its variety of trained grips: six different grips used in activities of daily living can be trained
• its adventure video game: the patients go through a real game that is involving them, and where they can practice ADL gestures
• its accessibility: it is available to a large public at low production costs
• its adaptability: each hand is different and thus the main dimensions of the product can be change to the various hand sizes

We achieved to develop a functional prototype with the main sensors of the device and paired it with a game prototype. Thus, we proved the feasibility of our concept. After correcting the flaws of the prototype, a test with stroke patient will be conceivable.

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