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# ReHoblet - A Home-Based Rehabilitation Game on the Tablet

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**Abstract**—We present ReHoblet; a physical rehabilitation game on tablets, designed to be used in a residential setting. ReHoblet trains two gross motor movements of the upper limbs by lifting (up-down) and transporting (left-right) the tablet to control a simple platform game. By using its accelerometers and gyroscope, the tablet is capable of detecting movements made by the user and steer the interaction based on this data. A formative evaluation with five Multiple Sclerosis (MS) patients and their therapists showed high appreciation for ReHoblet. Patients stated they liked ReHoblet not only to improve their physical abilities, but to train on performing technology-related tasks. Based on the results, we reflect on tablet-based games in home-based rehabilitation.

**Keywords**— Motor training, neurorehabilitation, physical therapy, tablet, pervasive healthcare, upper extremities.

## I. INTRODUCTION

Recently, mobile and pervasive technologies are becoming rapidly available to the society and are used as tools for a wide variety of daily activities. Several technologies (e.g. tablets) integrate sensors for movement detection. Games, that are developed for these technologies, can use the sensors to detect the user's movements and present a game concept that helps to enhance our physical abilities. Mobile technologies are also rapidly changing research and application domains in which they can be applied. An example of a particular application domain is rehabilitation; e.g. to detect movements that drive exercises or games for physical therapy for persons with a neurological disorder. The device characteristics and low cost of these mobile technologies enable physical therapy for a residential setting such as a rehab center, hospital, home environment or nursing home.

Neurorehabilitation is a complex medical process that aids the recovery of persons with a neurological disorder while minimizing the loss of their functional abilities. It requires patients to train intensively, usually three times a week for one hour. This physical therapy involves patients in personalized training exercises and progresses at a level of difficulty that is adapted to the patient's changing capabilities over time. For patients suffering from Multiple Sclerosis (MS), rehabilitation is a long and recurring process. Upper limb training focuses on regaining or sustaining functional abilities necessary to perform activities of daily living (e.g. eating a meal, washing their body). Some exercises involve manipulating real objects, under supervision of their therapist [12]. For physical therapy

to be successful, training exercises focus on repeating a set of specific and meaningful movements of the arms (e.g. lifting, transporting, reaching or rotations) at an intense pace. This set of movements represent the basic skill components that are used when performing activities of daily living [11]. The physical therapy typically progresses from training separate skills to training combinations of skills, depending on how well the patient masters the different skills.

As frequent and intense training is recommended, patients benefit from continuing training at home after their stay in a rehab center or in combination with an ambulant treatment in the center. Currently, most training setups for a residential context are rather static and are specifically targeted towards training individual and combined skills. Due to the repetitive nature of physical therapy, most commercial solutions do not succeed in engaging patients over a longer time period [4,6,10]. This greatly influences the possible therapy impact given a patient needs to intensively train and therefore they should remain motivated.

In this paper, we present ReHoblet, a prototype of a tablet-based rehabilitation game. Our contribution is based on a low-cost interactive setup for upper limb rehabilitation that can be applied in a residential setting. We use a 7 inch Samsung galaxy tab 2 android tablet to present and drive our ReHoblet game. A therapist can configure the rehabilitation game to the needs of a patient using an online portal, and check his progress during the training. We evaluated our system in a formative study with five MS patients and their therapists to refine our game concept and perception of tablet-based training systems.

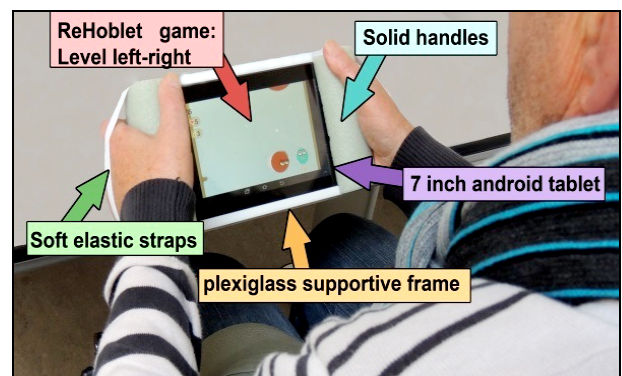


Fig 1: MS patient testing our ReHoblet rehabilitation game with use of the supportive frame.

## II. RELATED WORK

ReHoblet explores the use of tablets and serious games for physical therapy at home for the upper limb training of MS patients. Research on residential training systems is gaining attention and growing, but most related work on rehabilitation systems includes haptic, exoskeleton and robotic systems.

Haptic systems and exoskeletons provide force feedback and/or support (e.g. gravity support) for patients. A haptic system is the Individualized, Technology-supported and Robot-Assisted Virtual Learning Environments (I-TRAVLE) rehabilitation system [2,3,7]. This system supports physical therapy for MS and cerebrovascular accident (CVA) patients through personalized training exercises on different skills for the upper limbs. The system includes a MOOG HapticMaster extended with a custom-made ADL gimbal to support mild to severely affected patients. The software allows personalizing exercises in several manners; setting exercise parameters by the therapist [8]. The Armeo Spring of Biometrics [5] is an example of an exoskeleton rehabilitation system that helps MS patients to train skills of daily activities. The focus is on improving the muscle strength and functional capacity of the upper limb. Both systems provide physical support to allow the patient to train on difficult tasks with a realistic virtual environment. While these setups are useful in a hospital or rehab center, they are too expensive, impractical and large for home-based therapy without support of the therapist. These systems inspire us for the design of our game and therapist server, especially in designing from a skill components perspective and when incorporating adjustment of game parameters and monitoring of the progress of the patient.

Recently, neurorehabilitation research is focusing on mobile and pervasive technologies. Papangelis et al. [9] used off-the-shelf devices (e.g. iPad, iPhone or Kinect) to present physical exercises to children with Cerebral Palsy and collect performance data in real time. They investigated different rehabilitation games to engage children to exercise with the system. A server provides a tool for the therapists to make adaptations in the exercises and game parameters and apply event recognition rules for monitoring the patient's progress and analyzing the performance data. Their research inspired us for using a tablet as training tool, but we explore a platform game with levels for the different gross motor movements.

Curtis [1] et al. explored an interactive application on the tablet for handwriting skills for CVA patients. They designed four games that train different fine motor movements in handwriting such as target coordination, accuracy training, training on writing letters and words. Their games include a scoring system with audio feedback, reminders on the correct postures and persuasive text feedback to motivate the patient. Each of the games can be personalized to the patient's abilities and progress by setting various parameters by a therapist. The therapist can see an overview of the progress a patient made during the training. However, even if this research focus on fine motor movements, it shows the importance of feedback to motivate a patient and adaptation to the patient's abilities.

## III. UPPER LIMB REHABILITATION USING A TABLET

Many tablets include an accelerometer and/or gyroscope sensor. This allows them to detect movements made by the user, even subtle ones. Designers of mobile apps exploit this technology when creating games using motion data to control the application's behavior. Moreover, as tablets are commonly available at home, they have potential to support rehabilitation in the residential setting.

The tablet's design enables it to be portable and usable in different contexts. As patients with a neurological disorder often suffer from muscle weakness, the weight of a training object needs to be balanced to allow a patient to move it without making exercises too easy. Furthermore, size is also important to consider in a rehabilitation tool. As some patients experience reduced visual processing, the size of the screen plays an important role in their experience. A small screen will make it harder for patients to see details, but allows moving the tablet more easily, whereas a larger screen creates an opposite effect. Most tablets provide a 7' or 10' inch screen with capacitive sensing to detect touch events on the screen. These sizes still allow presenting details to a patient and keep the tablet manageable.

We created a supportive frame (Fig. 2) in which the tablet can be inserted by sliding it in the frame from the topside opening. The frame's main purpose is to support training on gross motor movements for the upper limb of patients with muscle weakness or spasms. Our frame design extends for most patients the uninterrupted time of use by allowing to move the tablet around bimanually. Moreover, it does not interfere with touch interactions in the game as these are designed to be in the range of the patient's fingers when holding the frame. The frame, firmly surrounding the tablet, is made from plexiglass (for stability) and keeps the tablet in place during the movements. The frame's two handles consist of soft isolation tubes to enhance stability, but allow for a grip with personalized thickness. The handles include a soft strap, placed around the patient's hands, to ensure the tablet will not fall if a patient loses grip or suffers from spasms. In our evaluation, we tested if our frame was needed to train with the tablet and if using both hands allows the patient to train movements which he would not be able to train by only using his severely affected arm.

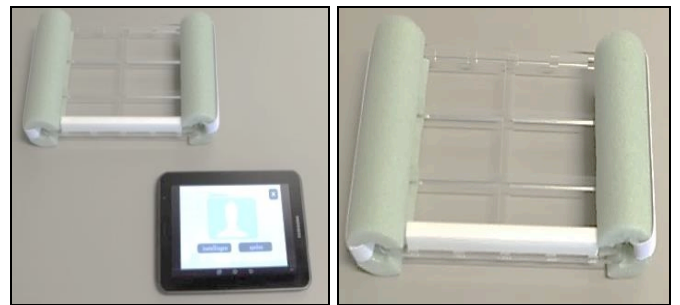


Fig 2: The ReHoblet system (7 inch Samsung galaxy tab 2 tablet with android) with plexiglass supportive frame.

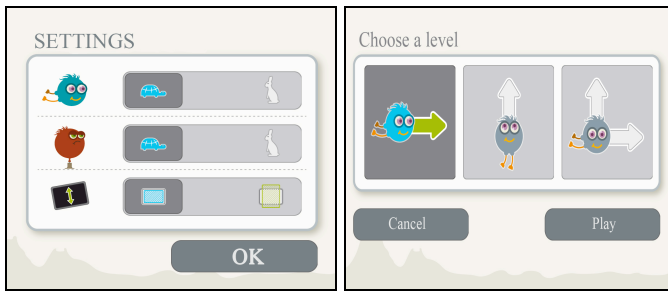


Fig 3: Personalizing ReHoblet to the patient's needs.

#### IV. REHOBLET- A MOTIVATING REHAB GAME

ReHoblet's game concept has been inspired by traditional platform games. The different game levels train different gross motor movements of the upper limbs of MS patients. The game allows the therapist to personalize the game parameters to the patient's abilities and progress.

##### A. Personalizing the game

For each person with a neurological disorder, the deficits can manifest themselves differently. Therefore, rehabilitation games have to be personalized to support a patient during the training and provide an adequate physical therapy. ReHoblet allows adapting different game parameters to the abilities of the patient. At the start of ReHoblet, the therapist or patient can access the settings and personalize the game. The settings only have to be set once and will be applied to all levels.

In the settings menu, either the patient or the therapist can set three options: the avatar's speed, the enemies' speed and the world size (Fig. 3). The avatar's speed influences how fast it will move through the game world. In addition, the enemies' speed will determine how fast enemies will move through the game. The final option for the world's size only applies to the level in which vertical movements are trained to move the avatar. This option creates a larger game world in which the patient has to perform larger movements to avoid enemies.

##### B. Gameplay using Gross Motor Movements

ReHoblet is a rehabilitation game for an android tablet to drive the therapy and motivate a patient to keep up the effort in long-term training. We developed a platform training game that consists of three levels to train two different gross motor movements (transporting (left-right) and lifting (up-down)) of the upper limbs. Two levels (Fig. 3) focus on one movement while the third level combines both movements by applying a turning point (Fig. 4). We chose for switching the direction instead of training both gross motor movements at the same time, because this provides variation in the game and allows a patient to focus on correctly performing the movement.

The patient moves the tablet to control an avatar (blue character in Fig 4-5) that automatically progresses through the game world. By moving the tablet, the avatar avoids enemies or catches bonuses (Fig. 5). Two types of enemies occur in the game; stationary enemies and enemies that can move around. The stationary enemies are like balloons which can inflate and deflate, and sometimes drift away. Enemies that can move are smaller fish-like characters which will move in a straight line in the avatar's direction.

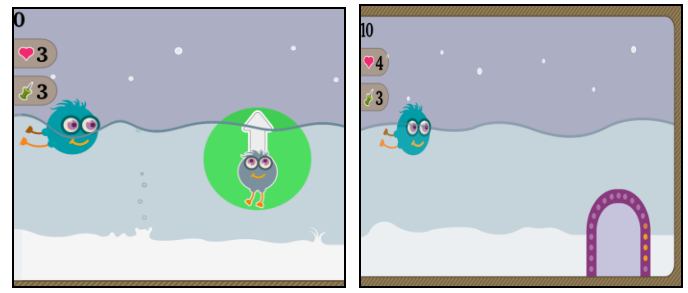


Fig 4: The special events in the game: (a) green turning point to switch the movement direction and (b) the portal to finish.

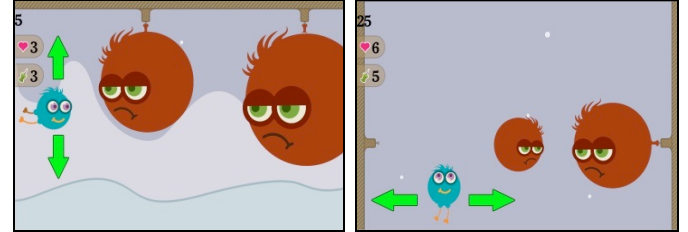


Fig 5: Two gross motor movements: (a) lifting (up-down) and (b) transporting (left-right) the tablet and avatar as shown by the green arrows.

Avatar lives are increased by catching a life bonus and decreased in case of a collision. To avoid enemies, the avatar has to pass them or attack them by moving the tablet shortly backwards to shoot a sting that trains the upper limb skill component of reaching (back-forward movement). ReHoblet also provides a third bonus; the photo bonus, which activates the tablet's back camera to let the patient take a picture of the training environment to share their experiences of training with the system with friends and family.

#### V. INTEGRATED MONITORING FOR THERAPISTS

We developed a monitoring system for therapists to check the training scheme and results of a patient at home.

##### A. The Web Server Tool for Therapists

After logging into the web server tool, a therapist gets an overview of the patients using ReHoblet at home. A first option is to view the patient data, game settings and a list of statistics from different training sessions. These statistics show an overview of the played levels, scores, the date and time, the number of bonuses caught and the number of enemies hit on different positions in the level. The bonus/enemy hit is directly related to the number of (in)correctly performed movements, as bonuses and enemies are placed in such a way that a patient has to perform the movement. The score, played levels and time relate to therapeutic metrics (duration and kind of movement exercises). Therapists use these statistics to check if a patient completes the required training sessions and to evaluate if there are difficulties with certain movements such as bonuses missed or enemies hit at specific range. The second option is to change the game settings in the monitoring application depending on the patient's results or meetings with the patient. In the current setup, progress measurement of the abilities of the patient is done using standard tests in a follow-up meeting with the doctor and/or therapist during which the training scheme, difficulties with the training and medication are discussed.

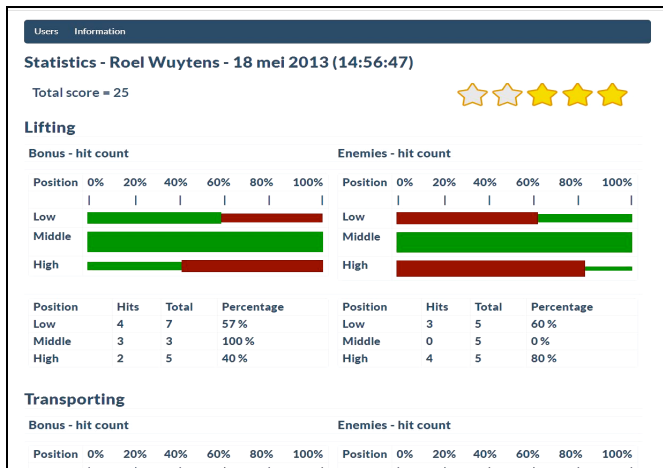


Fig 6: Statistics in the ReHoblet monitor

### B. NFC: Loading Settings on the Tablet

A therapist can create a unique NFC tag for each patient with the server tool. The patient can then simply load changes in his training scheme made by his therapist onto the tablet by scanning this tag that is linked with the patient profile on the server. The tag can be used to log into the game without remembering or typing a login. This eases the configuration step significantly, allowing for patients with cognitive deficits and/or severe motor deficits to get started quickly.

## VI. EVALUATION

Rehabilitation systems provide intense physical therapy to maximize the training results. It is important to adapt the design of the system to optimally fit the needs of patients and therapists by involving them in the development process of a rehabilitation system. We evaluated ReHoblet on the form factor of a tablet, supportive frame and game. This evaluation is part of an iterative design process in which we refine the game concept and supportive frame in physical therapy for the upper limbs of MS patients in a residential context.

### A. Experiment design

Our overall research goal is to investigate the benefit of pervasive technologies in (mainly neurological) rehabilitation systems for a residential setting. We performed a qualitative study with five MS patients and their therapists. After completing the informed consent for our experiment, they were asked to play three levels in our game in which different gross motor movements are trained. Afterwards, they were interviewed about their experience and their motivation for training with technology-based training systems.

The therapeutic effects of our system are expected to be equal to the effect of traditional therapy because we include the same movement exercises in ReHoblet. Therefore, we focused on the experience and design of ReHoblet in this study. A first aim of the evaluation was to investigate if the form factor of the tablet and supporting frame are sufficient as training device for persons with upper extremities. Secondly, we explored different designs and concepts in our serious game in search for motivating factors for serious games. Finally, we questioned patients about their motivation and experiences for training with a technology-based rehabilitation system.

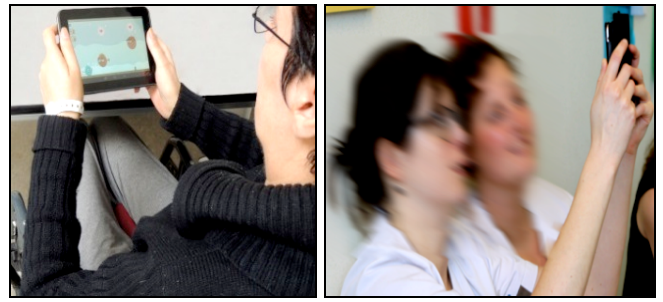


Fig 7: (a) Patient testing our game without the supportive frame and (b) therapists testing the lifting movement level .

### B. Procedure

The qualitative study of ReHoblet started by welcoming the patients. A short general explanation on our research and informed consent were given, followed by a short introduction on the game and procedure. Before patients played the game, we checked if they were capable of holding a tablet without the frame. If a patient could not hold the tablet, we placed it in our supporting frame and checked again. Patients played three levels which trained different gross motor movements (left-right and up-down). Therapists were asked to play the levels to determine the validity of the trained movements. During the test with ReHoblet, we observed how patients or therapists were using the system and took photos (permission through the informed consent) of their interactions with the system.

After testing the system, the patients were interviewed about their experience and preferences in a semi-structured interview. The questionnaire, used in the interview, focused on the technical design of the tablet and supportive frame, design aspects of ReHoblet and the experience of patients with the game, frame and tablet. We also asked questions on their preferences and motivation for playing games and including them in their rehabilitation. Finally, we debriefed and thanked the patients and therapists for their participation.

### C. Participants

ReHoblet aims for rehabilitation training for the upper limbs of persons with a neurological disorder. Eligible persons have difficulties in the upper limbs such as muscle strength and range of motion. However, patients still should be able to perform exercises without support (e.g. gravity compensation) or external tools as these are not available at home.

Five MS patients (three with progressive MS and two with relapse-remitting MS) participated in our evaluation. Two patients were male. The patients' age varied between 34 years and 66 years (average age of 51 years). All patients followed traditional physical therapy for the upper limbs and three patients received their physical therapy at home. Some patients were able to do household activities. Two patients had a tablet and worked with it in internet related activities.

In addition to the evaluation with patients, we also tested ReHoblet with therapists from rehab centre RMSC Overpelt. Four therapists tested ReHoblet before the qualitative study with patients. Their feedback on the game and movements has been applied before testing with patients. All therapists gave additional feedback on serious games and the tablet in therapy.

#### D. Results

The results of our evaluation revealed appreciation for and acceptance of ReHoblet as a rehabilitation tool. The patients' and therapists' feedback elaborates on possible future system properties and user preferences for tablets and gaming in rehabilitation in a residential setting.

In ReHoblet, we used a tablet as physical training tool for the upper limbs and to present a motivating rehabilitation game. Evaluating the tablet's form factor is essential for the overall evaluation of ReHoblet and user acceptance. Patients and therapists liked the form of the 7 inch tablet as it was large and bright enough to clearly distinguish game events without being too heavy or too large to manage it. Patients were very positive about the light weight and ease to hold and move the tablet. A first remark given by therapists (in contrast to the patients' experiences) was that training with both hands can result in the less disabled hand to compensate for the more disabled hand. However, patients stated that they would not have been able to complete all movements by only using their more disabled hand and that by using both hands they could support and guide their more disabled hand better. Another remark from therapists and patients was that the screen surface was sensitive at the sides where the tablet was held. This often resulted in the game pausing due to accidental touch events.

Three patients could easily grasp, hold and move the tablet without the supportive frame. The two other patients suffered from muscle weakness in their hands and tested with support of our frame. The patients who used the frame, were positive and highly appreciated the frame. They mentioned that they would never have been able to train without the supportive frame due to a weak grip in their disabled hand. The frame was evaluated by the patients as steady, supportive and pleasant to use. They even stated the frame was ideal for training with muscle weakness or spasms in the hands because the frame provided a sense of safety through the straps for fall prevention. The straps were found to be difficult to attach with muscle weakness in one or both hands without support of a therapist or family member.

Besides the tablet's form factor and physical use, patients and therapists also provided feedback on the game concept. In general, the participants found the game very understandable, challenging and pleasant as complementary training. They did not find the game too easy or too complex to play. For long term therapy, they would like to have more difficulty levels or events, which is clearly the intention when the concept is fully implemented in residential training. The turning point event was much appreciated by the patients as this event regularly changed the course of things in the game, thus keeping the attention of the player. Patients particularly liked the photo bonus as it provided variation and was more related to a real life activity. However, they only want to take and share pictures of their environment, not pictures of themselves or other persons involved in the therapy session. The meaning of the sounds for the bonus items was very clear to the patients. Furthermore, patients mentioned that the game would be more attractive if background music would be played. Finally, some buttons on the display, to start a level or select options, were difficult to reach and press by patients with muscle weakness in the hands as their fingers could not be moved very well.

Generally, all patients liked and appreciated a tablet-based rehabilitation game. They stated that they would like to use it at home as it would help them with their physical therapy and daily activities. Some patients even wanted to use the tablet for more general technology-related tasks than rehabilitation. In addition to individual training, patients would like to play rehabilitation games with family, a friend, a therapist or a personal assistant if they would get an equal chance to win the game. Their willingness to use social networks to challenge friends or share scores strongly depends on their preferences. The types of games, which are preferred by the patients, are quite diverse and depend on their personal background and interest. Their most profound reasons for playing games were: playing together, challenging others to improve their score, and challenging themselves to solve a problem.

#### VII. DISCUSSION AND LIMITATIONS

We evaluated ReHoblet with five Multiple Sclerosis patients with upper extremities and their therapists. Future development includes adding variations in the game concept and fine-tuning the design to overcome the above mentioned drawbacks. In this process, we adhere to a user-centered development methodology as much as possible, and we plan frequent prototype evaluation with patients and therapists. In addition to fine-tuning the game, an evaluation on the clinical effect of ReHoblet is another important point of focus in our research. This clinical evaluation takes place in the context of an applied research project on new rehabilitation approaches, I-TRAVLE. In collaboration with therapists, standard clinical assessment scales (e.g. Fugl-Meyer, ARAT or Wolf motor test metrics) will be used to determine a patient's progress and the effectiveness of training with ReHoblet. Furthermore, our research focuses on training systems in the patient's residential setting. A complementary study with patients on the use of ReHoblet in the residential environment (e.g. in adapted houses for independent living connected to a rehab center or at home) will provide more information on the applicability of tablet-based rehabilitation systems for the upper limbs in the residential setting.

Performance feedback is essential in rehabilitation systems for patients and therapists. Patients need to receive feedback on their performed movements and progress during and after training with the system. Personalized feedback on the movements will help to focus on the recommended movement path and avoid making compensations. In traditional therapy, a therapist is available in the training environment to check and correct a patient. Currently, we explore various sensor-based motion detection technologies that are suitable for residential environment and that can evaluate the performed movements in order to generate appropriate feedback to the patient. Recording a performance history and giving feedback on movement performance in training sessions that are not supervised by the therapists, are important to enable therapists to evaluate a patient's progress and personalize the system's parameters. The movement data can also be used to adapt the system's parameters automatically to the patient's changing abilities. Moreover, this information is valuable, especially as this is a telemonitoring feature of residential training systems.

Social interactions of persons with a neurological disorder are often limited when the disorder gets progressively worse. Traditional therapy sustains social interaction with therapists, but does not allow interactions with friends and family in the rehabilitation. In virtual exergames, social interactions such as sharing photos or playing a game together should be part of the training exercises [4]. These social interactions provide for an important additional motivation playing the rehabilitation game. Nevertheless, caution is needed when embedding social interactions into rehabilitation games to avoid creating the feeling for the patient of being patronized. Furthermore, the patient experiencing movement problems or weaknesses in the upper extremities should have equal opportunities and chances during the game as friends or family members.

To stimulate reuse and further development, we release the model of the supportive frame and rehabilitation game that were created for the ReHoblet system. In contrast with most current professional neurorehabilitation setups, we aim for accessible and affordable setups with this work. Our frame was created in a local Fab Lab – a freely accessible workshop with machines that allow for digital fabrication. Fab Labs are widespread and with the available machinery everyone is able to fabricate the tablet frame that is discussed in this paper. The assembly of the frame is straightforward. The rehabilitation game will be distributed using the existing Android play store from Google after the next iterations. Once the game is installed on the tablet and placed in the frame (whenever needed by a patient), the setup is operational and can be used in a residential setting. The monitoring system will still need to be installed in the rehab centers before being operational.

#### VIII. CONCLUSION

From the evaluation of our ReHoblet game, we gathered initial knowledge on the use of tablet-based rehabilitation games for physical therapy in the residential environment. ReHoblet implements a motivating tablet-based rehabilitation game for the upper limbs of persons with a neurological disorder. The gross motor movements trained with the system include lifting (up and down) and transporting (left and right) the tablet in order to control the avatar in the game (Section V). We evaluated ReHoblet with five MS patients and four therapists in a qualitative study (Section VI). Results of our evaluation showed high appreciation of our ReHoblet prototype and we were able to gather valuable feedback for future research and rehabilitation games and mobile, pervasive training systems.

#### ACKNOWLEDGMENT

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