Post-Stroke Rehabilitation Using Collaborative Robotic Therapy – Medical Purpose and User Acceptance

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***Abstract*—Strokes are the second leading cause of death worldwide. They are also the largest cause of permanent disabilities. Due to a demographic shift, the number of people suffering from strokes is increasing while the number of people working in the healthcare sector is decreasing. More than 80 % of stroke patients suffer from motor disabilities. This affects the activities of daily living. Due to the lack of staff in hospitals, stroke patients are discharged to a home environment early after the treatment of an acute stroke. Intensive training that focuses on simple repeatable activities patients can exploit rehabilitation potential. Having a learned non-use is detrimental to a person's rehabilitation. The risk of learned non-use occurring increases in a home environment, especially when the patient has no possibilities to exercise their impaired limbs. For this reason, a robot-assisted training method should help. It is necessary that the patient remains motivated to complete the rehabilitation and trains constantly. This can happen through the use of gamification, which means that exercises are introduced to the patient in an entertaining way. Furthermore, stroke patients usually struggle with social isolation, so it is important for the patient to still have contact with other people in the home environment. By integrating this environment into a robot-assisted training station, a possibility can be created. The long-term goal of this project is the development of a training station, that works with a collaborative robot, to enable a patient to have a positive therapy experience in the home environment. In the first phase of the project, a prototype of such a station will be created. The aim is to create an appealing human-machine interface from which a stroke patient can select exercises. Additionally, the patient should have the ability to play nine men's Morris with another patient or against the robot. On the first prototype volunteers test whether such a training station will benefit stroke patients. Furthermore, the volunteers provide feedback and suggestions for improvement to further develop the prototype.**

***Index Terms*—Stroke therapy, repetitive task-based and high-intensity rehabilitation, robot-assisted therapy, gamification.**

I. Introduction

A stroke is defined as a sudden neurological deficit. This happens through pathological processes that involve cerebral blood vessels [1]. This can lead to the disruption of the blood supply, which results in a lack of oxygen for certain regions of the brain and causes brain damage and the loss of certain functions [2]. Stroke is the second leading cause of death and the leading cause of long-term disabilities [3]. Approximately 60 % of post-stroke survivors suffer from long term disabilities and about 50 % of post stroke survivors suffer from hemiparesis. This means that one side of the human body becomes distinctly weaker and limited in its actions. As a result, approximately 30 % of post stoke survivors can not walk without assistance [4]. About 12.2 million people worldwide will suffer from their first stroke this year. Furthermore, about 6.5 million people die worldwide, after suffering a stroke [2]. The risk of experiencing a stroke increases with age – after the age of 45 the risk of suffering from a stroke doubles with each decade [5]. Notably 70 % of all strokes happen after the age of 65 [5]. Due to demographic changes the population of elderly people increases, and over a third of the population will be over 65 years in the year 2050 [6]. This demographic change also results in less people working in the medical field. Approximately one third of post-stroke survivors has to stay institutionalized after being discharged from an acute-care settings [7]. The remaining two thirds of post-stroke survivors return home but need a family caregiver or a professional caregiver at home [7]. About 31 % of post stroke survivors need help with caring for themselves [7]. This means that stroke patients will be in need to have support in completing activities of daily living (ADL). Some examples of these activities include eating and drinking, using a toilet, washing, doing the laundry, changing clothes or even standing up [1]. Approximately 80 % of all stroke survivors are usually unable to work after experiencing a stroke [8]. Additionally, dementia is a growing issue for elderly people, and cognitive stimulation helps to decelerate the process of dementia. Cognitive training is a crucial part of the rehabilitation process for stroke.

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A. Challenges in Stroke Rehabilitation

Most medical guidelines define the ischemic stroke as a medical emergency, that requires urgent hospital admission. This also implies that the stroke rehabilitation for patients should start immediately in the hospital [9]. After receiving acute medical treatment, patients are usually categorized based on their stroke severity [10]. The most common categorization system that is used for stroke patients is the National Institute of Health Stroke Scale (NIHSS) [10]. The NIHSS' strong ability to predict a patient's life after experiencing a stroke helps doctors and therapists to provide accurate information about and for patients set realistic goals for the patient's therapy and plan for discharge after acute hospital treatment is completed [11]. The most common impairment after a stroke is an impairment of the motor skills, the least common one is the loss of consciousness with less than five percent of patients who experience a stroke [10]. A patient's treatment during their stay in a hospital consists of four different parts, which are physiotherapy, occupational therapy, speech therapy and psychological therapy [12]. It is recommended that people suffering from stroke should undergo at least 45 minutes of each appropriate therapy every day [12]. The figure 1 shows how much therapy a patient actually receives per day in a hospital facility. As seen in Figure 1 the recommended therapy time is rarely achieved [12].

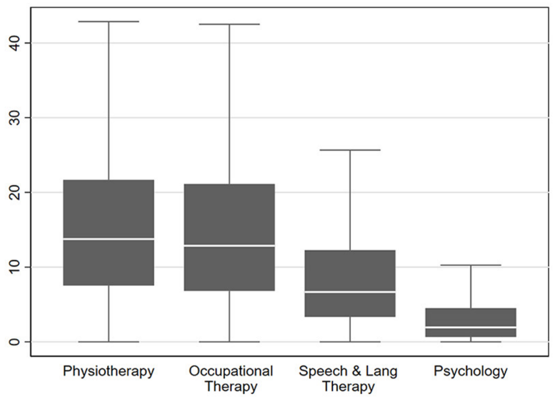

Fig. 1. Box plot of the amount of therapy a patient receives per day in a hospital facility [12].

1) Social Isolation in Stroke Rehabilitation: The most common definition for social isolation is a social network of less than three friends on which a patient can rely on [13]. An event such as a stroke has a lot of impact on the mobility of a patient. A patient needs understanding from not only their caregivers but also from their social group. It is found most effective for stroke patients to have a peer group suited on their level of impairment to do recreational activities together. Also a feeling of social isolation can vary for every individual patient. It is hereby important to suit the patient's need of including into the society, this can be achieved for example by connecting to their peers of any age on multiple occasions [14]. This can not only help the rehabilitation process but also have an impact for increasing the life span as shown in Figure 2. Furthermore a negative social surrounding of a patient can have a negative impact on the physical rehabilitation process. A negative social setting means people around the patient, who do not understand their special needs [15]. After a stroke about 80 % of all survivors are not able to work anymore [16]. The work place provides a social network, which stroke survivors lose and therefor are at high risk of depression [16]. Due to losing their social networks, about 50 % of all stroke patients suffer from clinical depression in the first year of the stroke [17] This also underlines the importance for a patient to have at least a few people in there surroundings, who understand or undergo the same process as the patient himself or herself.

B. Gamification in Stroke Rehabilitation

Gamification is defined as using design elements in a non-game environment which are characteristic for actual games [18]. It's importance is increasing in the field of health care to enhance motivation and support therapy [19]. It is used

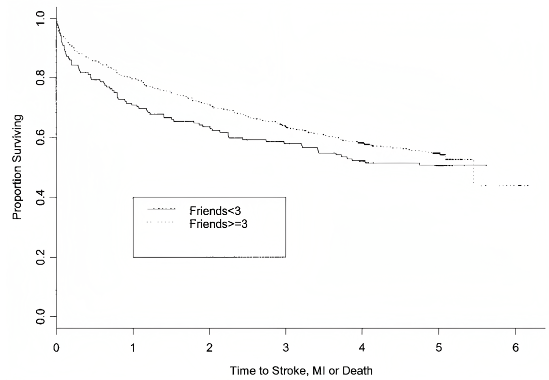

Fig. 2. The Kaplan Meier survival curve of stroke, myocardial infarction (MI), or death after ischemic stroke [13].

for activities, in which long-term engagement and continuity is needed for receiving a significant outcome for the patient [20]. Games also have cognitive elements, which a third of all stroke patients are in need of cognitive training in addition to their therapy regarding their motor deficits [21] . Moreover it is important for the patient, that the games are not regular games from commercials or standard app stores, which can be played on a console, for example a Wii, or a mobile phone, but there has to be a game or a task specific to the rehabilitation needs of a patient [22]. Otherwise it can affect the patient in a negative way, it could demotivate, stress or depresses a patient [22]. Also a major aspect of stroke rehabilitation is supporting patients to regain as much ADL back to patients, so that they would be able to live independently at home, only having a need for a caregiver if possible. Such exercises are considered functional exercises. Functional exercises can effectively improve physical functions and also the mental health status of patients suffering from hemiparesis following a stroke [23]. Especially functional exercises, which emphasize intense, task-oriented and highly receptive work-outs are very valuable for the rehabilitation process [24]. The patient should train in the post-acute phase at least 30 minutes daily to regain as much ADL as possible for the patient [25]. Fine motor skills are important for many ADL tasks for example like grasping little objects, which is considered an important skill in everyone's life [26]. It is important to use the affected limb as much as possible during the rehabilitation phase, so the patient does not suffer from so called Learned Non-Use (LNU), which means that the patient is learning at home to not use the affected limb for ADL, followed by managing these activities without the use of the affected hand. Therefore the exercise of ADL with the effected limb is very important to avoid LNU at all cost. Some of the mentioned ADL is shown in Figure 3 [27]. There are different tasks like using cutlery for preparing food or pouring water inside a glass. Also picking up coins or game pieces to train the fine motor skills of a patient are used as functional tasks focusing on ADL. The importance of these tasks is to use the affected arm for the exercises. To have patients not be able to use the healthy limb the hand will be put inside a mitten, to force the patient to use the impaired limb. This technique is part of the constraint induced movement therapy (CINT), where the goal is to have the patient do as much possible and as intense as possible with the stroke affected arm [27].

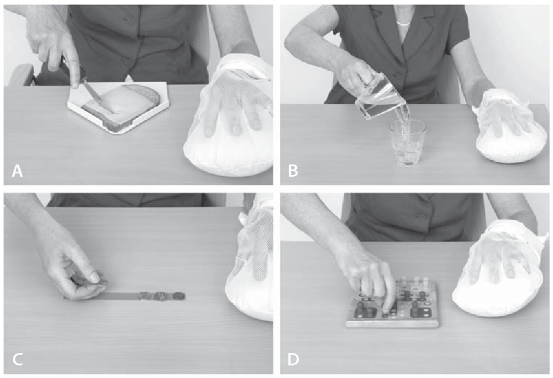

Fig. 3. Functional exercises focus on ADL with focusing on using the impaired limb [27].

Some disadvantages of the current commercial rehabilitation devices are that always a therapist has to be present during training and that a patient is not able to decide on his own to start a training with a rehabilitation device at home. Also a disadvantage of the current rehabilitation devices is that there is no social component during rehabilitation, which could increase the motivation of a patient and therefor also the rehabilitation process. Therefor the present study is aiming to develop a new training station, which includes a individual training at home and includes social components as part of the rehabilitation process. We also aim to investigate, if such a training station is liked by persons and if patients would like to train which such a training station.

TABLE I
REQUIREMENTS FOR A STROKE REHABILITATION DEVICE AND THEIR PRIORITIZING

Description of the Requirement	Importance
The patient has the option to interact with a different patient	Must
The patient has the option to use to interact with a different person in a therapeutic way	Must
The patient has the option to contact different patients and schedule social interactions	Should
The patient can interact with patient close to him to possible improve his social interactions outside the rehabilitation process	Should
The patient can easily use the social element of the rehabilitation device	Should
The patient has to like the Social element	Must
The games have to work well so the patient does not get frustrated	Must
The games should be graphically appealing to motivate a patient to practice	Must
The patient has a variety of different games	Should
The games have to have a therapeutic purpose	Must
Games can be used to test the patient's progress	Must
The games have to have different difficult levels so the	Must
Basis patients ADL have to be included rehabilitation is suited for the patient	Must
The patient has to like the concept of the rehabilitation device to be motivated during the rehabilitation process	Must
The games have to have a therapeutic purpose	Must
The patient has to feel safe during his rehabilitation	Must
The interface of the rehabilitation device has to be appealing for the patient	Should
The rehabilitation device has to support a therapist during the rehabilitation process during the rehabilitation process	Must
The therapist can decide which exercises and difficulties suit a patient	Must
The rehabilitation device has to collect Data for the therapist to show the patients rehabilitation process	Must
The rehabilitation device can use standardized test to show the therapist a patients rehabilitation process	Can

II. METHODS

The first step to complete the aim of the study is to collect requirements for the training station. Afterwards to build a training station, including social components, exercises and games. The next step is to conduct a evaluation of the training station and to gather information for further developments. We therefor let volunteers operate the training station and asked them to fill out a questionnaire. All experiments of volunteers were approved from MCI Ethics Committee.

A. Requirements for a Stroke Rehabilitation Device

For developing a training station for stroke rehabilitation different requirements for patients and therapist has to be full filled. The requirements have been created from state-of-the-art from Section I. Then we prioritized the importance. The importance of the requirement is either must, should or can. Importance with must have to be full filled in the first prototype Should is also seen as importance, but can be included in a further version. The category Can would be nice to have but is not crucial at the moment. The Requirements can be seen in Table I

B. Hardware Concept for a Stroke Rehabilitation Training Station

1) User Interaction Interface: To establish a connection between the various users and the system controller itself, an interface is required. The defined requirements state that this interaction shall be designed human-like, feature a display and a clear design. Regular check-ups with therapists and manufacturers led to the inspiration and finally the decision to choose a touch display as the main interaction interface. This gives the patient the opportunity to give input when prompted by the system by for example touching a button additionally to this manual input. For the project a special touchscreen was selected. To have a tablet know where certain elements like playing coins are, we found out that Tangible User Interface Objects (TUIO) could be used for recognizing different chips on the touchscreen. The system then can acknowledge the exact placing of such a chip onto the touchscreen and also the removing of it. TUIO does not only figure out, what is placed on the touchscreen but can also follow the movement of a chip on the touchscreen and also know the specific angle of such a chip. After some research we finally find a product, that is suited for the development of such a training station as a display. The display which is used in the development was called: "Multitouch Displays Scape® Tangible"and was produced by the company Interactive Scape, the display can be seen in Figure 4. The display has also the task to improve the patients training experience with an appealing HMI, which has to have some kind of gamification embedded to keep the patient motivated during the rehabilitation process.

Fig. 4. The Multitouch Displays Scape® Tangible,which is the display used in the robotic training station [28].

2) Robot Manipulator: As a substitution of the therapist a robot manipulator is selected to set up and deconstruct tasks for training and exercises. Contrary to traditional robots that can not be operated in close vicinity to humans individuals, a cobot is designed specifically for the use with patients. It ensures a safety by providing a feedback sensor system to ensure collisions are detected and no harm is caused in case of an unplanned incident. The UR5e from Universal Robot was selected for the initial concept and shown in Figure 5 as the manipulator. It features various safety functions, like having safety zones, where the speed of the robot is limited. This is important when the robot is moving inside a zone, where a patient could potential have his body parts in. The robot is provided with a vacuum gripper to transport the playing pieces for the different exercises. A robot manipulator is capable of moving fast and precisely to defined locations; thus waiting times can be minimized for the patient. The role of the robot is to be a companion and help the patient with preparation for the exercises and also help the patient in the clean up process.

3) Training Plate: To connect the user and the robot, a stationary location of physical interaction is defined. This resulting zone is called training plate, and features implemented devices like the interaction touchscreen mentioned in a previous section. This display is re-used as a input device for the various test and training modes that can be performed on the plate. The patient will have all his training onside the display. The display will then collect the various data collected during the patients interaction. The display also controls the robot and gives the command to move. The software of this communication itself is explained in another thesis [30].

4) Desk Concept: The three mentioned key features are combined on a rigid desk to provide a portable and easy to setup option. An initial render image is illustrated in Figure 6. It shows a wooden desk with the manipulator mounted on

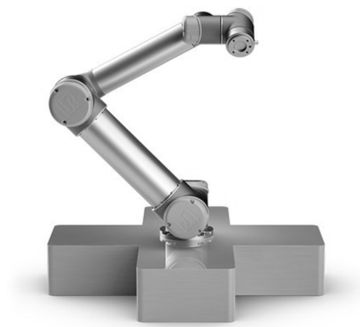

Fig. 5. Universal Robot Collaborative Robot UR5e [29].

it to reach the object and the training plate. One side of the robot manipulator playing pieces, that includes the chips, so the touchscreen can identify the object, are located that they can be gripped with the vacuum gripper and positioned at the training area on the display. On the other side there will be a second display, to have the possibility to interact with a different patient. The second display is not shown in the render image. To support the rehabilitation process the display will have the ability to flip. Because of safety reasons the flip of the display will be flipped away from the patient to reduce the risk of having the patients hand or fingers squeezed inside a gap. The coins then will be sorted by color and the robot will return the coins back to its tray.

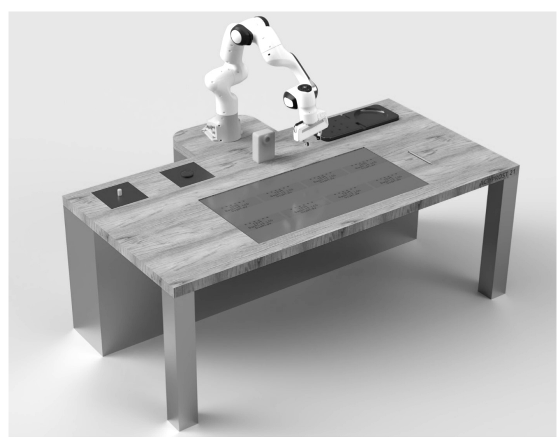

Fig. 6. Concept of the training station.

Further information on the software used for the concept and also the steering of the robot can be found in [30]. Also further information on the structural set up and also the safety components of such a training station is covered in [31].

C. *Exercises for a Stroke Rehabilitation Training Station*

There are different functional exercises for stroke patients to train and improve their motor functions. In the first prototype of the robotic training station, there should be three different exercises included for the patient to choose from. One of the exercise should be a game, which should be able to play with a different patient together. Also to keep it simple, there should be the same objects used for the exercises. The first exercise to include into the training station, is Coin Flipping. In a exercise a patient is picking up one of the coins, turning it around and placing it back in a specific region. The patient hereby is training his fine motor skills, which is also useful for ADL. Also the number of coins to flip can variable and make the exercise easier or harder for the patient. This is important so the patient is not bored, but also not overwhelmed of such an activity. It is important suiting the needs of a patient and giving different options of difficulty to the patient. For the therapist the time it has taken will be recorded. Thus the therapist can see the progress of the exercise and adapt the rehabilitation progress for the patient. The second exercise chosen to be implemented into the training is Coin Placing.

D. Implementing of the Patient Exchange Platform

As mentioned earlier a social component is crucial for fighting social isolation. To implement a social component into our training system this feature is being included into the application, which is used for the training on the rehabilitation training station.

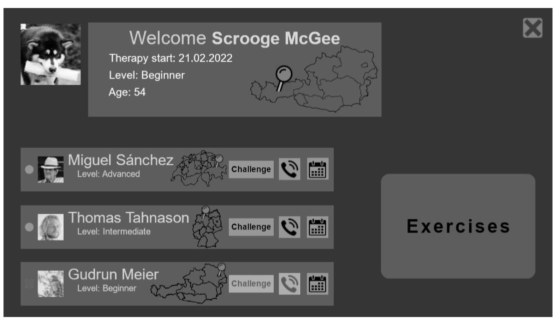

Fig. 7. Home-screen of the application used for the rehabilitation training station.

In Figure 7 the start screen of the application used for the rehabilitation training station can be seen. It is also personalized and should help a patient to stay motivated during the rehabilitation process. Also seen in Figure 7 is that it shows the different patients, who are online at the moment. The patient has now different ways to interact with the other patients. The patients also sees the different location of the other patients, so it could be possible for different patients who are locally close to become friends and meet up outside of the online world. The patient can start a video call with the other one via a tab on the telephone icon just as seen in Figure 8. The video of the patient will start on the second display. As we are only building a prototype yet we will include a video of a person in the development team from the same perspective, where a webcam will be included in a further development stage. So different training stations will be able to be connected.

In the application there is also a chat function included to invite other patients to participate in games together. This can be done through the calendar icon on the right side next to the person's name. This can be seen at the home screen in

Fig. 8. A patient can start a video call with a different patient to socially interact with them.

Figure 7. As seen in Figure 9, a person can select a day the patient wants to schedule an appointment with another patient to challenge the other patient and interact together, after the patient selects the desired day and tabs on the send button. The message will be saved and sent as well. As this model is yet a prototype the message will not yet be sent but with a higher number of different prototypes this could be implemented. The patient can also see the person they are inviting on the button of the screen. Moreover, the patient also has the option of returning to main screen with the arrow next to the word ”Menu”.

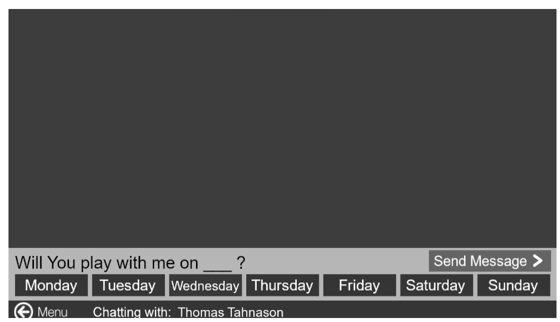

Fig. 9. A patient can also send messages to another person to invite them to a chosen day.

E. Implementation of the Exercises

This section explains the user interface of the application. Figure 10 shows the process by which users can navigate through the application. The application will begin with the start screen, which is shown in Figure 7 in Section II-D. From this screen the patient has many options from which to choose. The social interactions will not be discussed further as they have been already explained in Section II-D.

Each patient also has the option to exercise without another human being. The home screen includes a button for this feature which is demonstrated in Figure 7. After pressing this button, the patient will then be directed to another screen to choose one of three exercises. As seen in Figure 11, the screen displays three buttons by which the user can select the desired activity. The patient can also return to the Menu, if the exercise button was selected accidentally.

If the patient selects either coin flipping or coin placing, he or she has the option to choose a difficulty setting. The

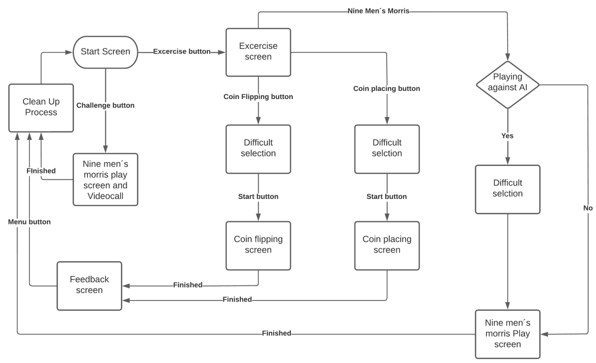

Fig. 10. The flowchart showing how navigation through the application is possible for patients.

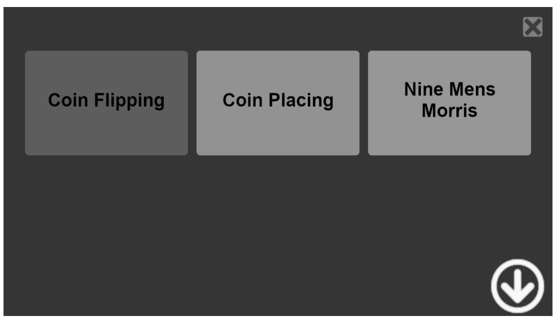

Fig. 11. The patient has the option to choose from 3 different exercises.

proper setting can be advised from the therapist to help further in the rehabilitation process. Further, the choice ensures that no patient feels overwhelmed by an activity or, conversely unchallenged-both of which would negatively impact the patient. Therefore, a patient can select between very easy, easy, normal, hard or very hard difficulty levels by ticking the desired box. Next, the a patient can then click on the start button. The patient has the option to change the setting as often as desired. Further into the exercise the patient can to return to the exercise screen by clicking on the arrow pointing to the right and select a different practice session. This is illustrated in Figure 12.

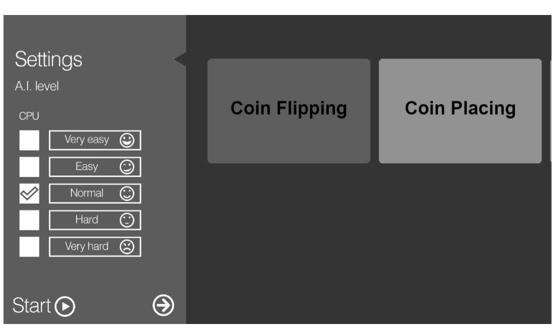

Fig. 12. The patient can to select the difficult setting suited for the patient.

1) Nine Men's Morris: As mentioned above, one of the games patients can play is Nine Men's Morris. The patient can choose between playing against an artificial intelligence (AI) or playing against another human being. The patient can also select a different difficulty level from the AI. The AI used in this application is not part of this thesis. The code used for the Nine Men's Morris was developed by Miguel Oliveira and Afonso Caldas and can be accessed online through Github [32]. These developer's design elements, such as the sliding elements and difficulty settings, were also used [32]. The patient can also return to the menu using the arrow buttons. Figure 13 shows the screen for choosing the difficulty level. Further, the possibility to choose who will be the opponent, the AI or another human player, if there is one present, is included on this screen as well.

Fig. 13. The patient can select the difficulty level of the AI or choose to play against another human.

2) Coin Flipping: When the game Coin Flipping is started, the application sends commands to the robot to prepare the game for the patient. Different red circles appear, the number and location depending on the selected difficulty. The robot places the tokens, which look like coins, on the display. The display acknowledges that the first coin is placed and sends the next command to the robot to place into the red circle. This repeats itself until all coins are placed into their red circles. After the last coin is placed, the application waits approximately two seconds until the instruction video starts and all circles turn green. This symbols the patient that timing has started. When the clock begins, a stopwatch symbol in the upper right corner starts and the pointer is moving in a clockwise motion. On the instruction video a hand is pictured, which takes and flips the coin and places it back into the circle, afterwards the circle is turning blue. The blue circle symbolizes that a coin flip has been detected. Also an interim time appears in the upper left corner to provide the patient with feedback on how much time he or she has needed to complete a flip. For every flip the patient will get a time feedback, how much time has passed since the last flip. The coin has ID-tags on each side, which are connected with an identification number, so the application knows whether a coin is correctly flipped or another coin is moved inside the circle. The application only identifies a flip if the correct ID-tack is located inside the green circle. Figure 14 presents the screen shown to the patient. After the exercise the patient receives feedback from the feedback screen, which will be explained in a further paragraph.

3) Coin Placing: The final exercise implemented in the application is Coin Placing. When this exercise is started, a command is sent to the robot to carry a coin from the tray to the middle of the screen. The screen then recognizes,

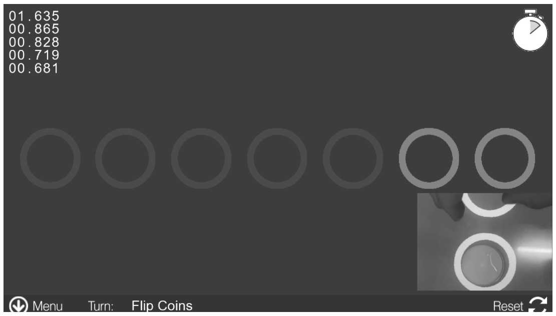

Fig. 14. The screen for the game coin flipping. In this picture the game is currently not finished and not all green circles have turned blue.

that the coin is placed on the tray. The application waits approximately 2 seconds for the robot to move out of the patient's space. Right after that the instruction video will start. In the video a coin is placed into the moving red circle. Further another symbol, indicating the timing for the patient has started, appears. This symbol acts in the same way as the timing symbol used in Coin Flipping, a symbol placed in the upper right corner. When the clock starts, the pointer moves in a clockwise direction. The patient should do the same, and place the white coin from the screen into the moving red circle. After the screen has identified a placing into the red circle, a interim time appears in the upper left corner. Then a new moving red circle appears. This circle indicates the upcoming spot in which the next coin has to be placed. The previous ring a patient had to move the coin into is marked with a blue circle on the screen. This process is repeated in the setting "very easy" four more times, so a patient has to place in total five coins. For each difficult setting the number of placed coins increases by an additional coin placing. After the patient places the last coin, the feedback screen appears and the patient receives a feedback on the exercise try. This screen is depicted in Figure 15.

Fig. 15. The screen for the game Coin Placing. In this picture the game is unfinished and the patient has to move the white coin into the red moving circle. The previous spot is marked with a blue circle.

III. Results

As part of the evaluation volunteers are asked to test our prototype and give valuable feedback for further development in this project. The HMI was tested with different volunteers with different ages, sex and background. Different aspects of the training station are evaluated to see where further development should and could be done. After participating, volunteers filled out a questionnaire. To participate in our evaluation the volunteers are handed a information sheet. The sheet included a quick overview on what the project is about. In addition to the project description it is explained that each volunteer will interact with a robot, which although the robot is a collaborative robot, has still a certain risk. Further it is explained that each participant can freely interact and explore the HMI. The participants could and are more than welcome to ask questions about the concept. A member of the project team is always there to help, if any problems or questions would occur to assist and advise the volunteers at any time. After the volunteers could explore all features and interactions with the training station, which took around 15-20 minutes, we kindly asked each participant to fill out a form anonymously, to give us their true opinion of the project. On the questionnaire there are a total of 20 questions, in which participants are asked to judge a statement from 1-6, which ranged from strongly disagree to strongly agree. There are also open questions, where a participant could give any input he or she wanted. The questionnaire and information sheet, which also included the participants' informed consent, are available in German as well as in English to give everyone the opportunity to read and fill out the forms in their preferred language and to not exclude any volunteer. Score 1 (strongly disagree), 2 (disagree) and 3 (slightly disagree) has been seen as negative feedback. Score 4 (slightly agree), 5 (agree) and 6 (strongly agree) are considered positive feedback.

A. *Evaluation of the Overall Concept of the Training Station*

First of all the overall acceptance of the training station was evaluated. Our participants were asked how they like the concept of the training station. As all the questions are written as a statement the first statement to be answered on the English questionnaire was verbalized as "I liked the concept of the training station."At each statement there are six boxes as mentioned above to tick off one's opinion. 33 out of 34 participants have given a positive feedback for the concept of the training station. Only one person is not as convinced of the idea as the others and gave a score of only three, more detailed answers on possible why's will be discussed later. Approximately 76 % have even given the best possible grade (6) and highly agreed to this being a good approach on rehabilitation.

The background for this question is to evaluate if people are actually interested in such an idea and if a care robot with such features could have a future impact or rather not. If the answers would have been shifted to the negative side, it would show, that participants are not convinced of this concept and by trend it is possible to say, to come to the conclusion that either the whole idea of a care robot might had to receive another thought, if it is just this particular concept or if it might be a time factor that society right now might not be ready yet for a technology like this. However, as the answers actually have been quite positive on this statement, the actual concept overall is well liked and the base structure seems to be well adopted by the participants as an idea for training.

B. Evaluation of the User Acceptance

Furthermore it is interesting to know if participants would use such a training station if they were in a situation where they would need rehabilitation. This is to figure out if there would be an acceptance by the users. Over 94 % of participants either agree or even strongly agree on using such a device for their own rehabilitation if they were in the situation to. The participants also had the option to answer why or why not they would want to train with such a training station. Only five participants filled this out. Three people said that they would like to interact with a human. As mentioned before such a training device would not be the only rehab tool but rather supporting a therapist in their rehabilitation plan. Continuative the training station would not replace any personal human interaction with the patient, rather complement it after the therapist's time per patient has ended. Another comment is that it is a good use of time and it is fun and useful for training. Another participant added that staff will have to use even less time personally in the future and it is a great idea and concept, that will hopefully be even more developed. This answer is being interpreted as therapists have more time they can use to train with patients with more complex tasks that are yet beyond this care robot.

C. User Feedback

The participants were asked, what the liked about the concept of the training station and also what they personally would improve in a further development stage. Out of 34 participants 30 people have answered that question. To start with the positive feedback eleven people have complimented on the User experience and wrote that the training station is easy to use, good structured, patient friendly, modern and appealing. Eight people liked the games and are writing, that the social component connected with an online game is a good and innovative idea, they also liked that there are different difficult levels to choose from, so a patient is not getting bored from a too simple task and also does not get frustrated from a task that is too challenging. Four people have said that they like that a robot can interact with a human and that the robot is playing for another human being, who is currently not on the same place. Six people comment on the safety and rehabilitation process and address the display and all components being big and therefor easier to handle, that the gamification is helping the rehabilitation process through distraction. Also the participants like the explaining videos, which made clear what is expected from a patient at a specific exercises. Also the tracking of the process is mentioned from a participant, who also like the combination of being able to choose to interact only with the robot and also the possibility to be connected to another patient. The partakers are also asked to make suggestions on how to improve the prototype. Overall 22 out of 34 people have used the open format to propose an improvement. Nine participants wrote that the robot is moving too slow and that the speed should be increased. This issue is understandable, however, the speed in the near field of a patient is limited on purpose due to safety reasons. A lower speed can also reduce the impact of the collision and is also protective, because a patient can more likely see in which direction the robot is moving and can move aside and prevent a collision from happening. The robot itself is a collaborative robot and will stop immediately for the safety of the patient. Another suggestion which is made by six participants that the noise which is due to the vacuum gripper should be reduced. This could be done in another step of the prototype, because a professional vacuum gripper would be more quiet. Four participants also gave the input that the HMI could be extended through music and voice, to have a patient feel much closer to a human interaction. This could also be a part for further steps for an advanced prototype. Another four people suggest that more games and exercises should be implemented to have a greater variety for a patient. This is definitely a great idea and will also be implemented in a further step. Since the purpose of the prototype is clearly to just prove the possibility of the concept and not to include a lot of games and exercises, mentioned improvements have not yet been part of the project. Two person also suggested that errors in the games should be changed, which have been changed already afterwards. Another participant wants to improve the material of the coins, which can also be changed in a further step of the prototype.

IV. Conclusion

As in the previous Section mentioned the results of the evaluation are all in all good for a first prototype. There is definitely room for improvement, but the prototype is developed for showing a prove of the working concept which is developed in section II. As mentioned in the section III 97 % of the volunteers, who participate in our evaluation, gave a positive feedback on the overall concept of the training station. This is also shown in the high user acceptance towards such a training station in an rehabilitation setting, with a rate of 94 % of all participants. A very crucial part of the evaluation is the part, in which participants give feedback on parts they like about the training station and also parts the do not like. The participants like a lot that the display and interface are big and easy to understand. This is really important for the developing team, to have the interface very intuitive and is shown at a big display, so elderly people have not a problem with using it and understand it easily. Also patients after suffering from a stroke are not as good as healthy people, because of their neurological impairment. This can differ from patient to patient, but this still has to be accounted for. Also the different difficult levels are liked from the participants. This is important for having a good personalized experience for the patient. So a therapist could easily suggest a difficult level to start for the patient, and if the patient is overwhelmed or not challenged enough, he can then change it on his own, to have the level of difficulties suit his personal need. That is important to have the patient staying motivated to exercise during the rehabilitation process. But also suggestions for improvement are made from the participants. The biggest issue for the participants is the noise from the vacuum gripper, which is for most of the participants too loud and in a certain way disturbing. This issue should be resolved in a further step of the prototype by using a professional vacuum gripper, which is quieter than the solution used in the current step. To improve the HMI the training station should include a audio feedback or should be able to talk to a patient. This suggestion is good and would be considered to adapt to the training station in a further step of the development. The last big suggestions from the participants is to increase the speed of the robot. This is a very tough decision, because the speed of the robot is limited on purpose to have a certain level of safety for the patient. Also in an event of a collision between the robot and a patient, the outcome would not be as severe as in a case, where the robot would move in a higher speed. So that suggestion would be hard to adopt. To summarize all previous results, the grading and the feedback of the participants are overall good. Since it is the prototype it is normal to have small suggestions for improvements. Nevertheless, for being the first prototype of such training station the user acceptance and interest of the users to see further developments are very high.

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