Design Intervention for Indian Elderly to improve Hand Flexibility and Range of Motion

B.Des Design Project II

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Approval Sheet

The project titled Design Intervention for Indian Elderly to improve Hand Flexibility and Range of Motion by Nebin Biju is approved for partial fulfilment for the degree of Bachelors of Design.

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Chairperson:

Internal Examiner:

External Examiner:

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Nebin Biju

Contents

Abstract

Body metabolism slows with age. This in turn reduces the activities that the elderly can do. It is found that people doing physical activities tend to improve their immune system, digestive system, bone density, blood pressure, reduced heart attacks and it even helps in reducing depression and anxiety in elderly. These illness hence can be reduced significantly with simple exercises, proper therapy and rehabilitation. Stroke patients and fractured individuals constitute another significant groups that require physiotherapy and rehabilitation.

Rehabilitation programs are time demanding and often requires regular practice. When western countries are slowly advancing in their improved healthcare system and tele-rehabilitation programs, with the constant increase in elderly population majority of the Asian countries especially the ones in the Indian subcontinent are yet to tackle the issue effectively. The existing facilities of therapy and rehabilitation are not accessible to significant part of the community due to poor health care system and affordability. Absence of proper rehabilitation facilities after hospital care is also a major reason for patients to discontinue the course of the program.

As hand functions are fundamental in activities of daily living like easting, brushing, bathing, holding etc., rehabilitation and physiotherapy of hand is considered critical. This project aims at providing a platform for the elderly to improve their hand flexibility and range of motion. Contextualised to Indian population, this affordable and simple setup helps the users to continue the rehabilitation program after their hospital care. The tasks setup by the therapists are carried out by patients with simple gestures that connects with the exercises. Coupled with a relatable character, the game avoids boredom which is a major problem associated with less adherence to exercises.

1. Introduction

Elderly population is growing rapidly in India [1]. This is an obvious consequence of the process of demographic transition. When many of the western countries are prepared to react to the ageing population, the concept is relatively new to most of the Asian countries including India. An interesting fact about ageing Indian is that elderly is much higher in rural areas (constituting 80%) than in urban areas [2]. Limited accessibility and affordability of health care facilities and programs are the major problems faced by the rural India. 30% of the Indian elderly lives in poverty [2]. Many senior citizens in our country are unable to live an independent life.

Ageing also results in reduced body metabolism. Any impairment or any loss of movement skill has a great impact in the quality of life. As hand functions are fundamental in activities of daily living like easting, brushing, bathing, holding etc., rehabilitation and physiotherapy of hand is considered critical [3]. Apart from ageing, impairments in hands due to alternations of motor functions is also frequently observed in people affected by various neurological and musculoskeletal diseases such as stroke, cerebral palsy and arthritis [3]. Bad posture during work repeated working on non ergonomic environment also causes chronic illness resulting in spasticity, inflammation, reduced motor control capabilities and chronic pain leading to problems like incorrect action of grip or tremor [3].

A large part of body malfunctions can be improved by proper physiotherapy and exercises. Lack of motivation to complete the course of the program, lack of follow up, social and economical constraints, and nature of the exercise programs are some of the reasons why the adherence to exercise is less in elderly [4]. Many drops the extremely repetitive and monotonous routines that have to be followed in a rehabilitation process that has to be usually continued life long. When efforts are being made to continue the program at home, lack of communication with the therapist and the lack of self monitoring of their own improvement reduces the motivation in people. This calls to the need of an affordable platform where the patients can actively continue their course without out any problems. Motivation of the participants should be prime when it comes to physiotherapy and rehabilitation. When it comes to hands, the exercises are aimed to strengthen the muscles around the fingers and wrists to allow the increase in flexibility, better range of motion of joints, movement performances and movement coordination with which the activities for daily living can be achieved with ease [5].

2. Motivation

It was during my 2108 Summer Internship with the NGO - Universal Design and Assistive Technologies (UDAAT) Foundation, I was exposed to the different kinds of rehabilitation and physiotherapy for Cerebral Palsy (CP) kids at Adarsh Special School, Kochi. I was fortunate to design and make cheap and easily replicable assistive devices for Activities for Daily Living (ADL) for about 25 CP children. The designs were successful and are still used and followed by many. During my course there, I observed the challenges faced by them while doing physiotherapy and rehabilitation. Many were from the poorer sections of the society and was unable to afford the available products which are predominantly western. It was a struggle (even though they didn't consider it as one) for the parents to bring the children for daily checkup travelling significant kilometres.

The second instance is from my grandfather who did physiotherapy for a major fracture on his wrist. He didn't complete the course due to various reasons. Lately, he was advised by the doctor to do certain hand exercises with a sponge ball. He appears to be bored with the repetitive actions and is least interested to continue it.

It was these two incidents which motivated me in choosing this topic. Lack of motivation and limited affordability and accessibility were the major problem faced in a physiotherapy program. By digging little deeper into the topic, I came to know that there is a significant population that is in need for a solution. Incorporating existing technologies to design an interactive solution for the Indian population was my initial brief. Reading about exergames and interesting interactive medias kept me motivated again. The journey continued from there and through this project I am proposing a design intervention for the Indian elderly to improve hand flexibility and range of motion by engaging them with activities/games.

Fig 2.1. User testing of the designed products at Adarsh Special School, Kochi.

3. Secondary Research

Physiotherapy and Rehabilitation program is an extensive and complex process. The course of the program is confined even after clinical therapy through the means of telecommunication technologies under the name of telerehabilitaion [4]. Proper monitoring and guidance is very much essential for a positive outcome. Completing the course of a rehabilitation program is very much necessary for better recovery. However a research study by Alankus et al. [7] suggests that only 31% of the patients performed exercises performed by the therapists. And an other significant number didn't complete the course. There are several factors associated with the less adherence to exercise and physiotherapy programs. Collective insights from secondary and primary research are listed below:

1. Barriers associated with the exercise program

Most the exercise programs are repetitive, monotonous and time demanding. Older people who are not used to these kind of extensive tasks feels overburdened with the number of tasks that they have to do [4]. Exercises are also stopped when they feel that it is not doing them any good. Apart from that elderly don't even try to do some exercises because of its complex nature [4]. Boring nature of exercises are another reason to the less adherence.

2. Barriers associated with the healthcare journey

There is a significant gap observed after the clinical care is done and the patients are taken back to home. Patients feel that the care has hence reduced and this creates a sense of abandonment in them [4]. Adding to this is the huge communication gap between the therapist and the patient [4]. This leads to lack of follow-ups and the program gradually ends.

3. Barriers associated with affording equipments

There are many technologically advanced equipments available in the market. Many people especially the poorer sections of the society are unable to afford them. This will lead them to do the exercise in a traditional way which will gradually end the course of exercise due to its monotonous nature.

4. Barriers associated with patient representation

Wrong perception of patient about the disease and the exercise is a factor which reduces the adherence. Considering it as 'not curable' and doing exercise might again worsen the situation is a common belief in many elderly [4]. Despondency is another factor associated with this. People lose interest over time thinking when are they getting better [4]. This leads them to

make false beliefs about exercises and physiotherapy program. Depression among elderly arising due to dementia is also a serious factor [2].

5. Barriers associated with environmental factors

People doing therapy likes to connect with other people especially the ones with their similar conditions. Elderlies in the Indian families are usually the odd ones when it comes to diseases and illness and they feel awkward doing exercises at home. Doing group exercises in care homes have solved this issue to an extend. There is also difficulties in planning and organising exercises programs [4]. Lack of recreational space in Indian cities can also be a barrier [6].

Researches have suggested some strategies and methods to enhance the adherence of participants to exercises [4]. Having a personal instructor at home would solve the problem to a large extent but the situation is not realistic most of the times. Others approaches to enhance the adherence can be by increasing the attractiveness of the program by making it more engaging and immersive, providing right feedback and favouring the feeling of being supported.

There are many tools designed and developed which are out there in the market that tackle the mentioned barriers to some extend. They can be broadly classified into three types [4] -

1. Reminder tools - that give users personalised reminders in the form of messages, calls or emails.
2. Exchange tools - that provide a platform for patients and therapists to share experiences during rehabilitation
3. Tools to improve performance - that are aimed primarily at improving the performance of the disabled part.

Introducing a game-play in these tools under the name of Game therapy is becoming very prominent now. It is a form of therapy that uses games to perform activities or exercises that are required for rehabilitation. Research has proved that game-based therapy is very much efficient in keeping the participants motivated to continue the rehabilitation [8].

Existing games

The Block and Box Test (BBT) is a quick, simple and common test practiced globally [9]. It measures unilateral gross manual dexterity and can be used with wide range of population. The test equipment consists of a wooden box which has two compartments with a partition in the middle. One of them will be filled with small blocks. The objective is to transfer the small blocks from one container to the other in a given time. The BBT score is calculated by the number of blocks transferred. Participant’s hand should cross over the partition in order for the point to be given. Higher scores means better manual dexterity. The therapist sits opposite to evaluate. Other most commonly practiced one is the Grooved Pegboard Test [10]. This dexterity

test twenty five holes with randomly positioned slots (Fig. 3.1). The participants have to rotate and put the twenty five pegs which have keys on one side to match the holes. The time taken is noted. This test is a measure of manual dexterity. The most commonly used score here is the completion time. A supervision of a therapist is required here. The Minnesota Manual Dexterity Test (MMDT) [11] is another standardised test to evaluate a participants ability to move small objects over different distances (Fig. 3.2). By making the participants to arrange pegs on a peg board, the test measures their rapid eye-hand coordination as well as arm-hand dexterity.

Though all the above mentioned activities or games can be used to asses improvements, they are not adaptive to a person's skill set and requires constant monitoring. They largely lack a fun game-play to keep the participants motivated. Self assessment and progress data is not available for the participant and he/she is completely depended on the therapist. This is a hindrance to the telerahabilitation program.

Digital based physiotherapy is largely solving many of these issues of tracking and feedback. Spina et al. [12] developed an interactive game which takes advantages of the built in sensors of the phone to monitor the exercise and provide acoustic feedback on the participants performance and the error done. The feedback monitoring system enable the participants showed them their daily progress and kept them motivated. Khademi et al. [13] from the University of California made a

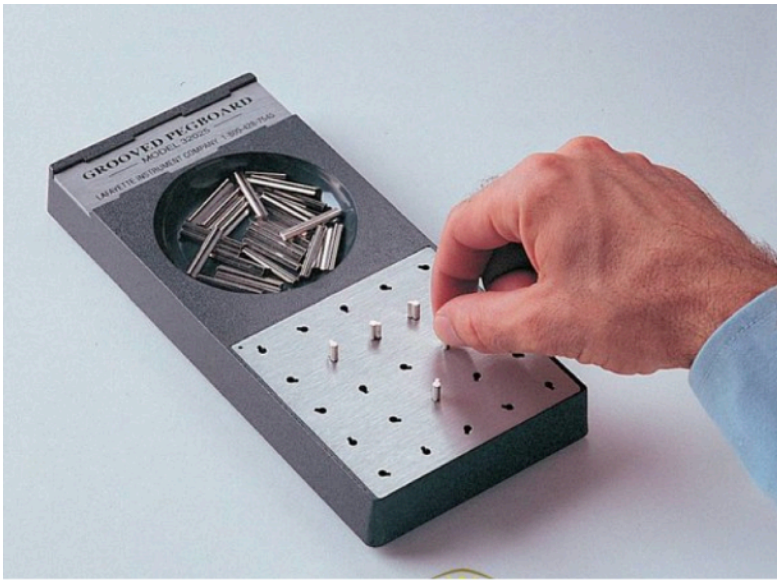


Fig 3.1. Grooved Pegboard Test.

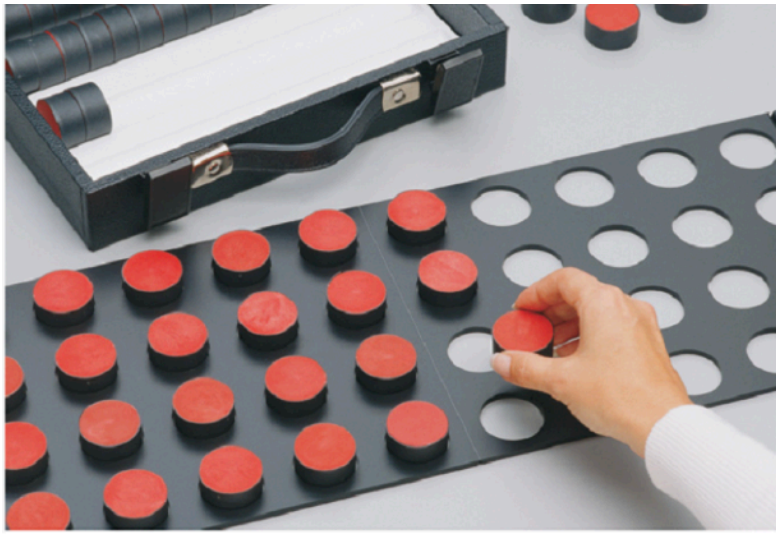


Fig 3.2. Minnesota Manual Dexterity Test.

rehabilitation game inspired form the popular game Fruit Ninja to explore the difference between direct and indirect interaction while doing the rehabilitation (Fig. 3.3). The game includes activities which are similar to the BBT test and measures the manual dexterity with accuracy by plotting the coordinates of the participant's hand which holds a 'Cup'. The movements are captured by the cameras. The main aim here was to divert the participants attention to the game and this proved the effective nature of the computer-assisted therapies in rehabilitation. Broeren et al. [14] Explored the advantages of using Virtual Reality (VR) technology in tele-rehabilitation with the help of robotic arms and sensing devices (Fig. 3.4). QikRehab [15] was an interactive exercise tool developed by Joe et al. which is specifically designed for fine exercises like pinching, gripping, rolling and twisting (Fig. 3.5). The feedback and monitoring system helped the medical professionals and therapists record and assess the progress. Commercially available products like Nintendo Wii, Microsoft Kinect and Sony PlayStation have been used for rehabilitation [16]. They are mostly not designed for a specific exercise purpose, needs longer time to setup and requires additional time from the therapist to perform multiple actions simultaneously. More importance was given for the development of the hardware by the companies [15]. Hence it is inconvenient for the patient to practice. A user centric approach was therefore necessary to balance the effectiveness

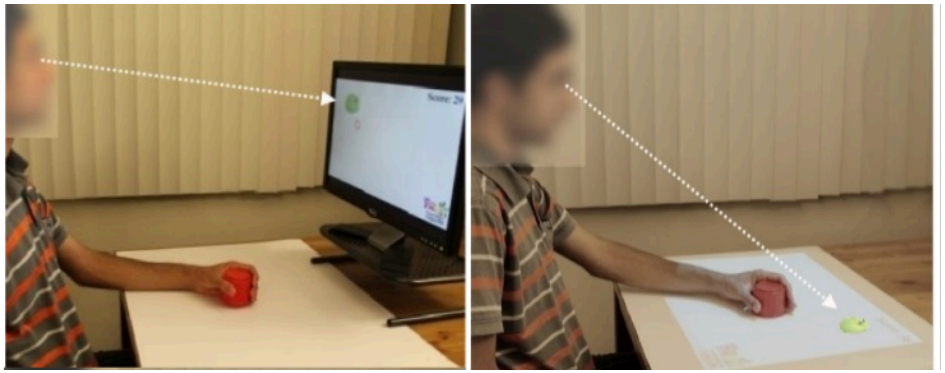
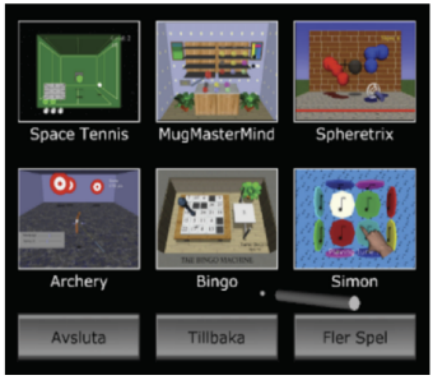


Fig 3.3. Measuring the manual dexterity with accuracy by plotting the coordinates of the participant's hand on a surface with a camera.



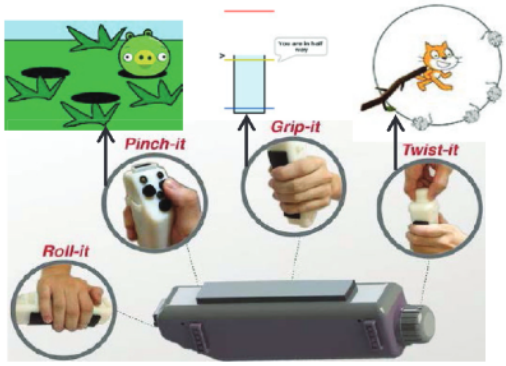


Fig 3.4. (left) The interface of the VR game used for tele rehabilitation by Broeren et al. Fig 3.5. (right) QikRehab, an interactive exercise tool developed for fine exercises for hands.

4. User Studies

Primary research was conducted with therapists and elderlies to understand the process of rehabilitation and the nature of physiotherapy program, adherence of elderly towards technology and challenges faced by them.

Multiple discussions were done with physiotherapists (n=2) and an expert who works with the elderlies and latest technologies in person and over phone call.

Some of the key questions asked include -

- What are the stages included in rehabilitation?
- What are the exercises recommended for hands?
- How is the process evaluated?
- What are the reasons for patients discontinuing the rehabilitation program?
- Do you recommend home based rehabilitation?
- What all products are used by you for rehabilitation?

Following are the collective insights from the discussions -

- Giving activities to elderly is a very common practice that is done in physiotherapy. This usually include putting beads (different weights, shapes, size and texture) on thread, mixing dough, separating grains, crumble and straighten towels of different texture.
- Exercises generally follow a FITT (Frequency, Intensity, Time, Type) approach.
- Each sessions should try to cover maximum number of joints.
- Maintaining the right posture while exercising is very much important.
- Usually each session lasts for ten minutes and is performed thrice a day.
- It is advisable to avoid sudden jerks and movements while exercising.
- Patients often tend to find shortcuts while doing exercise, hence strict monitoring is necessary.
- "*Isme Kya!*" - Very simple activities also make the elderly people less motivated thinking that the outcome can be less and feels childish. Looks of the tool plays a major role. Little bit of complexity in the equipment is important.
- It is important to always make the elderly feel that the activity/ exercise is important and they are gaining something/improving, thus the importance of feedback and tracking.
- Data interpretation is a problem when presented in technical terms.
- Most elderly have little knowledge about their illness and its cure.
- Elderlies are ready to invest if it show signs of improvement.

It was also important to understand the elderlies, who are the main target users. Semi-structured interviews were conducted with elderlies (n = 9, Male: 6, Female: 3, Age Group: 64-82 years) who are doing or are in need of physiotherapy to understand their interests, daily routine and challenges faced by them in doing daily activities. In some cases caretakers and the children who helps elderly are also important stakeholders. They were also interviewed to understand the situation better.

Some of the key questions asked include -

- How is your daily routine like?
- How often do you exercise?
- What are your hobbies?
- How do you contact a doctor? Do you keep in touch with him or her later?
- Are you a smart phone user? If not, do you want to use one?
- Are you confident about your health?
- How much are you willing invest on an exercise product?

Following are the collective insights from the interviews -

- Most of the elderlies have their day started early, a very few had a set routine.
- Majority of them are open to learn new technologies like using a smartphone.
- Elderlies like living with their family and children.
- They like to be independent in doing their daily activities. Depending on their relatives for smaller activities reduced their self confidence.
- Most of them are ready to invest in medical equipments if they show signs of progress.
- Most of the elderlies have a personal doctor whom he/she is in contact with and they call them up when needed. Most of the cases it is either a local doctor who is into homeopathy and Ayurveda.
- Elderlies are particular about their health and thus motivated to do exercises. But various factors like the nature of exercises lack of availability of resources reduce the adherence.
- There is a dedicated time for praying, chanting and for other religious activities.
- Watching TV (mostly news or religious serials), listening to radio, reading, playing with grandchildren, helping with small households are the major hobbies. Listening to old songs brought them joy.
- A very few (only males) went to the nearby club houses in the evening.
- Small art and crafts related activities were liked by many.
- Many had difficulties understanding English.
- Newspaper advertisements, phone calls and TV are their main source if information.

5. Exercises

After consultations and multiple discussions with physiotherapists, the exercises to be included in the system were selected. The selected range of motion exercises for hands can be broadly classified into -

1. Ulnar - Radial Deviation
2. Flexion - Extension
3. Finger Lifts

Exercises for hands are primarily aimed at improving the posture, flexibility, range of motion ans strength. Monitoring exercises and giving appropriate feedback is equally important as doing exercise. Right posture, ample timing, right intensity and appropriate repetitions are crucial while doing exercise. The FITT (Frequency, Intensity, Time and Type) principle is a great way of monitoring your exercise program. This outlines the key components or training guidelines, for an effective exercise program.

Frequency - is the measure of how often you workout
Intensity - is the the measure of how hard you workout
Time - is the time taken for the workout
Type - is the type of exercise that you do

It is important to track the exercise and to keep a check whether the exercise is done right. Tracking can be categorised into four levels - Posture Tracking, Repetition Tracking, Exercise Tracking and Session Tracking. Generally an exercise is repeated 10 times in a session. Three sessions are done in a day with each lasting 10-15 minutes.

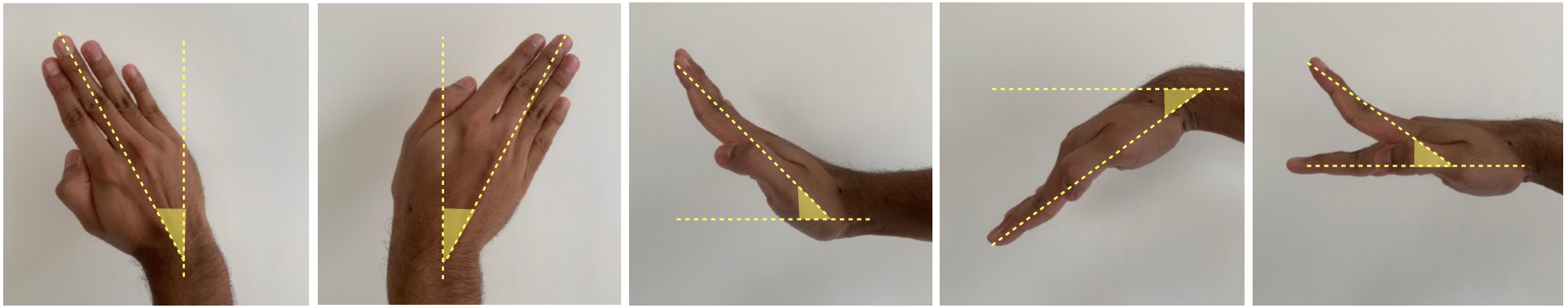


Fig 5.1. (from left) 1. Radial Deviation 2. Ulnar Deviation 3. Extension 4. Flexion 5. Fingers Range of Motion

6. Project Brief

From the insights of primary and secondary research, it is identified that the characteristics of the new design should be accessible, affordable and motivating for the patients. There should be proper tracking mechanism where the physiotherapist can analyse and make changes in the course. An appropriate feedback should be given to the participants to self analyse and motivate themselves should also be given importance.

The objective of the project is as follows -

To design a platform for the Indian elderly to improve hand flexibility and range of motion by engaging them with activities/games.

Following are the goals of the project -

1. Increase motivation to continue the rehabilitation process
2. A proper feedback mechanism to track the progress
3. Reduced complexity with the apparatus and content
4. Contextualised to Indian population
5. A record keeping mechanism of data for future reference

7. Ideation

Six different ideas were made and after discussions with faculty members, experts and evaluating on the basis of the selected factors (Increase Motivation, Feedback Mechanism, Appropriate Complexity, Contextual to Indian population, Record keeping of trackable data, Easily Affordable), three ideas were selected and made into concepts. Mockups of concepts were made to do Pilot test 1 and assessments of each concept in detail.

Idea 1 - Keep Counting: An exercise tool inspired from the counting machine which the elderly uses while chanting

Idea 2 - Frugal Much!: An all in one exercise tool which can be developed within the house with available materials. Lacked tracking and feedback.

Idea 3 - Something Musical: A musical instrument turned exercise tool where the user can exercise while playing music.

Idea 4 - Shoot Em: An interactive tab-based application where gestures related to exercise are used to achieve certain tasks

Idea 5 - Create, Play, Note: An exercise tool where the user can create patterns using rubber bands, play with it and note the progress.

Idea 6 - Magic Board: An interactive tool with a controller connected to a PC/Tablet/Smartphone with an application where exercises and its tracking can be done by playing a game.

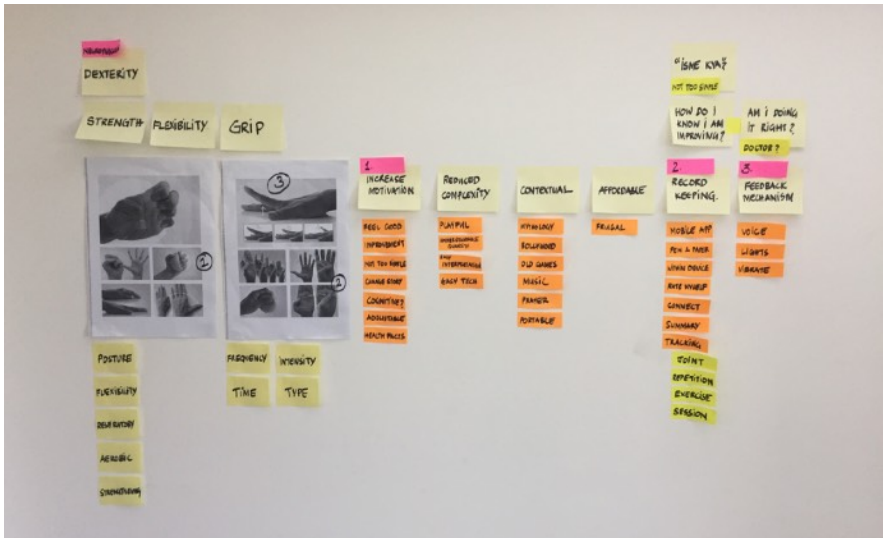


Fig 7.1. Ideation process on white board with sticky notes.

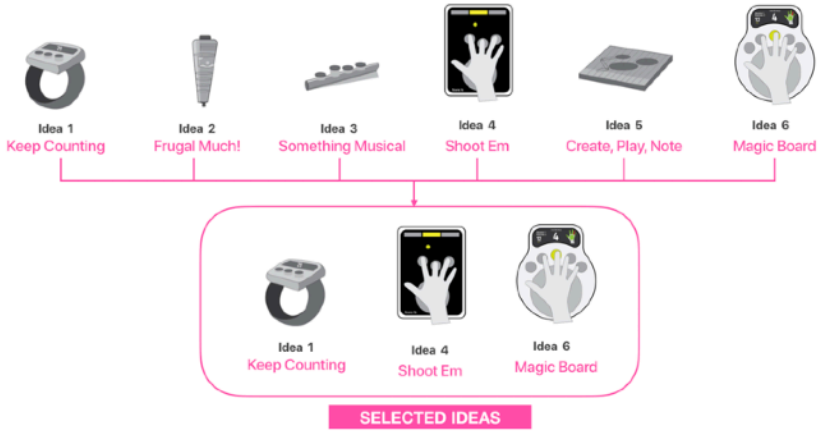


Fig 7.2. Three ideas were selected from the six initial ideas.

8. Selected Concepts

Concept 1: Keep Counting

Inspired from the existing counting equipment, this concept has press buttons of varied resistance that are used for counting. Primary research showed that chanting was an activity that almost all elderly did and this equipment takes advantage of this fact to increase motivation while exercising. Worn on fingers like an adjustable ring, the equipment helps the user to track the count and time of the exercise. The time can be set before and haptic feedback is given at each sets/intervals. When worn in different fingers the equipment can be used to do different exercises. Easy portability and affordability is the plus point of this concept when compared with other two

Keep Counting 2.0

An upgrade to Keep Counting. This is a sensor based counting system which enables the user to do the exercise without any restrictions. This comprises of a finger wearable with a proximity sensor attached and is connected to a mobile phone with an application installed. This keep a track record of the exercise and gives real time feedback in the form of visual and audio. A small demo of the exercise is shown with the help of a video so that that user can mimic it. The application follows a linear flow and gets completed only when the session is completed. The application also provide provisions to collaborate with the physiotherapists so that interactive telerahabilitation is possible

Fig 8.1. Keep Counting 2.0.

Concept 2: Shot em!

A tablet based interactive game that encourages the elderly to press and slide through certain baits thereby making them do the fine exercises with related gestures. The content of the game can be changed by the therapist according to the needs of the user. This primarily uses the touch and swipe gestures to do the exercises. The involvement in the game is motivating enough to take the boredom away. The number and time is tracked and the user is progressed to next level according to the improvement. The difficulty increases with each level.

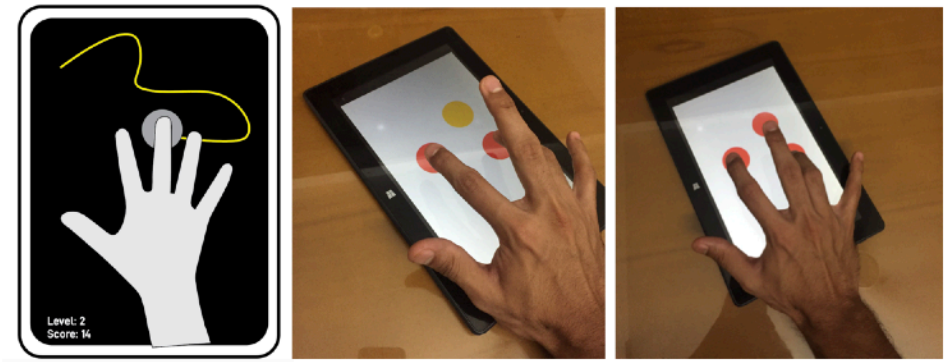


Fig 8.2. Shoot em!.

Concept 3: Magic Board

An interactive product aimed exclusively for improving the flexibility and range of motion of hands. The product has a rotating disc where the palm is rested, five sensor based buttons where the fingers are rested which detects the proximity of the fingers and a display that shows the essential data (Time, Date, Improvement, Session, Type, Position) required for the exercise. This can be connected to a mobile phone with a personalised application and the activities have to be done accordingly. The product works without the mobile too. The app stores the exercise data, the degree of improvement and the correctness of the exercise. This data can be shared with the physiotherapists or doctors and suggestions can be received. Limited data can be stored and initiated without the app as well. The improvement shown motivates the user to use the product and the content (Bollywood or religious) makes the exercises less boring. Magic Board could cover all the selected exercises. Constant tracking and feedback is a plus.

Fig 8.3. Magic Board.

9. Final Concept

Initial evaluation of the selected concepts were done after Pilot Test 1 with the mockups and taking feedback from users and expert. Each concept was given a score out of five against the six selected factors after various discussions and Magic Board was chosen as the final concept.

	Keep Counting	Shoot Em!	Magic Board
Increase Motivation	2	2	4
Trackable Data	3	1	4
Feedback Mechanism	4	3	4
Right Complexity	3	2	4
Contextual to India	5	5	5
Easily Affordable	4	5	3
Total	**21**	**18**	**24**

Fig 9.1. Score for each concept against the factors considered.

The Magic Board consists of a controller which can be connected to a Personal Computer, Tablet or a Smartphone wirelessly. With the application (game) installed, the participants can perform certain gestures to complete the asked tasks in the game. Trick was to connect the gestures in the game with the selected exercises. The primary research showed that it is important to give simple and relatable gestures so that cognitive loads in the initial stages are less. An example could be a simple hand extension gesture to jump could be easily related and hence learned fast. The evaluation of range of motion is done with angles and time which are made while doing the tasks. The collected data can be shared with the therapist to improvise on the course of rehabilitation.

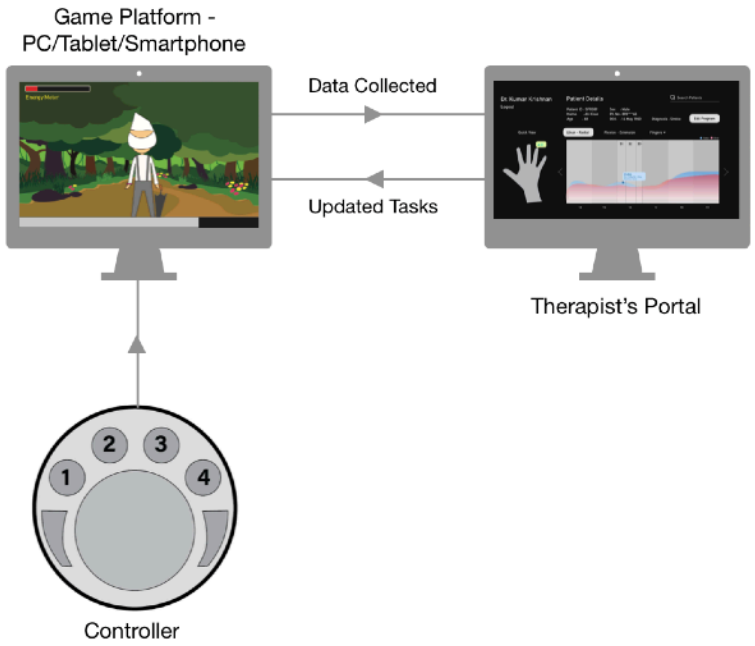


Fig 9.2. Overview of Magic Board.

Pilot Test 2

Second Pilot test was conducted with the mockups made. A theme was developed for the game which was based on Ramayana as an outcome of the primary research. The game narrates the story of Rama going to get Sita from Ravana. On this journey, he encounters many obstacle and should overcome those to find his beloved wife. By different gestures done over the control pad at each step, the objective can be achieved. Simple actions like extension for 'jump', ulnar and radial deviations for 'aiming' and flexion for 'sliding' were used. The participant was introduced on the rules of the game before hand. The responses in the games were simulated in relation to the actions performed. The concept was reviewed by experts and their feedback were taken into consideration.

Following are some collective insights from the user test and the expert feedback -

- Users tend to forget the right gesture that has to done at a particular instance. Keeping a run-time reference might help to reduce the cognitive load.
- "*What next?*" - the game ended without providing the user with any information on what he/she should do after.
- The ergonomics of the control board has to be reconsidered as the thumb was not able to fit in.
- Even though the content depicted the Indian epic and was contextualised to India, abstract games and themes related to Indian traditional games or comics were more inclusive for a diverse audience.
- "*Did I do well?*' - This was a question that a user asked. So a need for comprehensive improvement/progress chart after the session in an understandable format is raised.
- The playfulness in the tasks was appreciated.
- It is better to avoid aggressive actions like shooting/killing while designing a game for elderly.

The insights from pilot test 2 was taken into consideration and changes were made.

Fig 9.3. Second pilot test.

Controller Pad Design

A new controller pad has been made with ergonomic considerations. The display board which was there in the earlier design was removed and the feedback and tracking screen was incorporated in the application. There are four circular touch-pads for the four fingers and two dedicated touch-pads for the left and right thumb. The controller pad works well for both the left and right hand. There is a rotating plate on which the palms are to be rested. This helps in achieving the radial-ulnar deviation of the hands. A circular marking is made for the joints between the palm and fingers to be placed so that accurate measurements could be taken with the help of sensors.

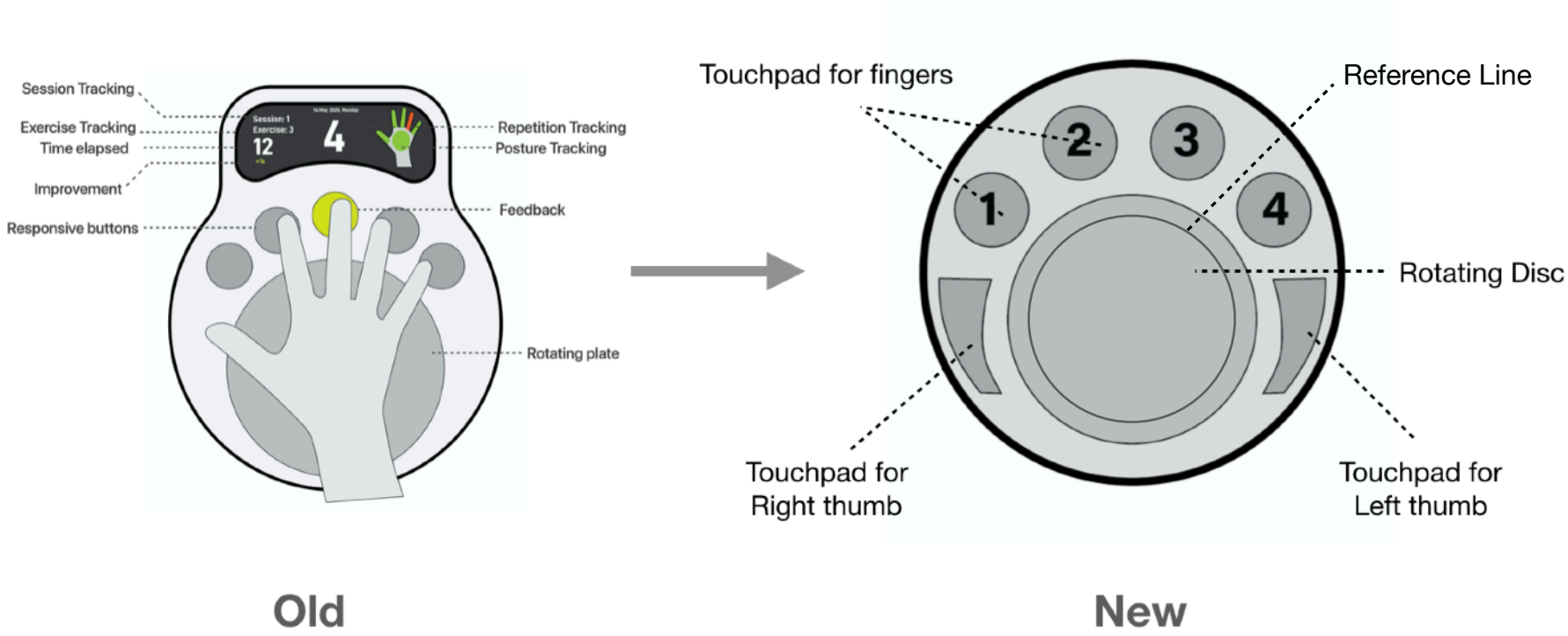


Fig 9.4. The old controller (left) and newly designed controller (right) after second pilot test.

Content Development.

Developing content for the application was an interesting task. It was important to keep a relatable storyline for the elderly so that they won't feel bored while doing the task. Most of the elderly tend to be religious and are aware about their religious stories. Connecting the storyline for the game with that of Mahabharata and Ramayana was a way to go. But abstract games and connecting the theme with other traditional Indian games/comics was a more inclusive approach for the diverse Indian population.

Chacha Chowdhary was a character known by majority of Indians [17]. Most of the elderlies as well as children enjoyed the acts of intelligent old man who solved problems smartly with little bit of humour. "*Chacha Chaudhary ka dimaag computer se bhi tez chalta hai*" is a famous dialogue remembered by many. Inspired from Chacha Chowdhary, a new character 'Chachaji' was developed in way that the participants could relate to Chacha Chowdhary and to retain the Indianness. Chachaji was a smart old man who is physically fit and leads an independent life. He has a pet cat named Chottu. Magic umbrella and Pink Smart Watch are his priceless assets. Storyline based on each incidents was made into a game for a session. The game was named 'Adventures with Chachaji". Fun acts were incorporated to make the gameplay interesting.

Each session followed a straight narrative and task flow was in one direction. The user will be introduced with the objective for the session. By completing the tasks while playing the game, the objective is achieved. A comprehensive report of the user is shown after the session is completed. An abstract game - "Bouncing Ball" with the similar gameplay was also made in parallel. Examples of other games can be found in Appendix 1.

Fig 9.5. Chachaji - The main character of the game with his pet Chottu.

Fig 9.6. An Instance from 'Adventures with Chachaji" and "Bouncing Ball" .

Data Collection and Feedback

Data Collection and Feedback of the exercise is very much important and plays a vital role in motivation and improvisation during the course of rehabilitation. There are differences in the kind of feedback that the patient and the doctor receives as their needs are different. Feedback enables the user to self asses their progress and gain confidence. While it helps the doctor/physiotherapist to analyse the progress and suggest changes. The gameplay is rich with data. The controller sensor can provide the doctor/physiotherapist with data of the frequency and duration of the sessions and the range of motion of joints. The data collected can be transferred to the therapist's profile which can be accessed by the therapist for understanding the patient's progress and thereby helping to make suggestions and improvisations for the course.

The therapist portal gives an overview of the data collected from the game in a format that is useful for the therapist. Day wise progress is shown in a graph format. Upon hovering on the graph the day splits into sessions and important data like the duration of session and angles are shown. The graphs are categorised into three namely, Ulnar-Radial, Flexion-Extension and Fingers range of motion. The improvement can also be quickly understood with the help of quick view by hovering over the hand image shown on the left. Patient's general details including the date of join and what he/she is diagnosed for is mentioned clearly on top. The portal also allows the doctor to search other patients with the name or Patient ID. There is a provision to edit the course of the program according to patients progress.

The whole purpose of the patient portal or the patient's feedback screen is to keep him/her motivated and to have a quick update about their progress in a simple format. A performance index (progress achieved from the last day in percentage) is calculated from the data and is shown in comparison with the previous day's performance. A quick health tip is also shown to keep the users aware about healthy practices and lifestyle.

Fig 9.7. Feedback screen for therapist.

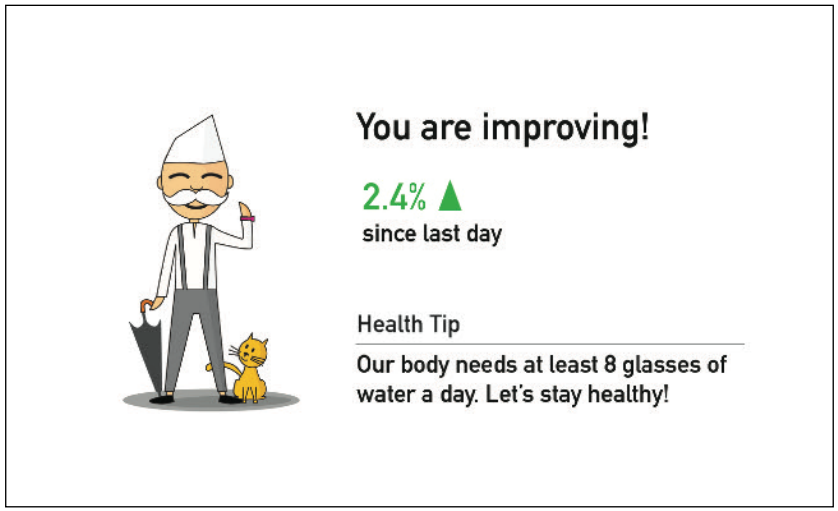


Fig 9.8. Feedback screen for patients.

Working

The working of the system is simple. All the measurements are taken in millimetres. The distance between the reference point and the finger tips or hands are measured with the help of ultra sonic sensors. Knowing this distance and the distance from the sensor to the reference line, the angle (which is needed for evaluating range of motion) can be calculated with basic trigonometric equations. The angle for the radial-ulnar deviation can be directly calculated from the rotation of the disc calibrated with the help of a sensor.

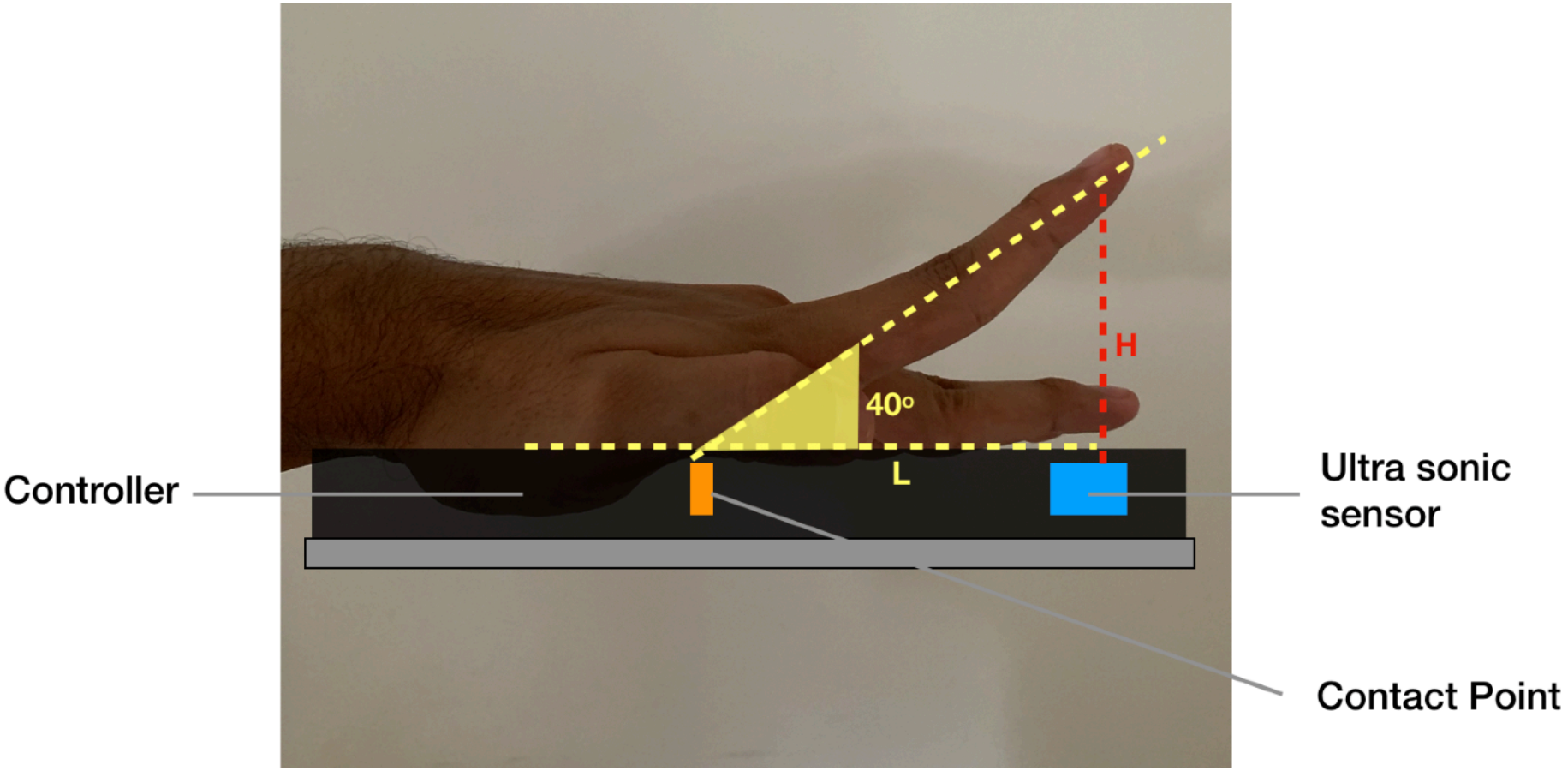


Fig 9.9. Schematic representation of the working of controller.

User Journey

The game flows a linear and unidirectional flow. Following is the step by step progress of a session -

1. The session begins with a Welcome Screen (Fig. 9.10).

2. Upon pressing '1' in the controller, a scenario is established in the beginning which has to be completed by the participant. An example of 'Finding Chottu' is addressed here (Fig. 9.11).

3. Once the scenario is established, the configuration screen appears. Here the participant has to carefully place his hands as asked so that the right posture is calibrated and hence the chances of error is least (Fig. 9.12).

4. The user is directed to a configuration conformation screen which gives a green light to start the game (Fig. 9.13).

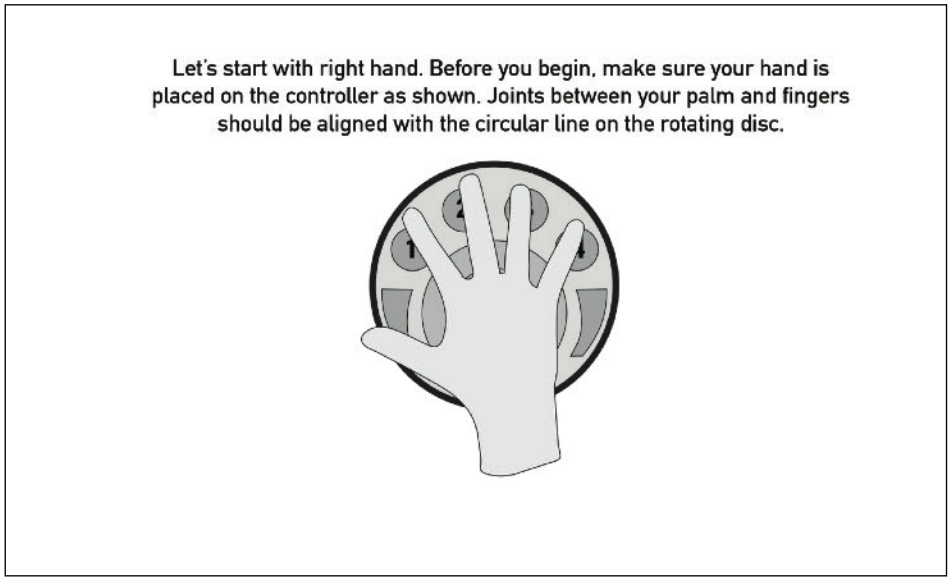
5. After achieving the right posture, the game starts. Here the participant has to do certain gestures to perform the desired action. The details of which is given in the following pages. The required gesture is also shown in a small box in the game screen so that the participants won't forget it. The live progress of the game is shown in the form of a bar at the bottom of the screen.

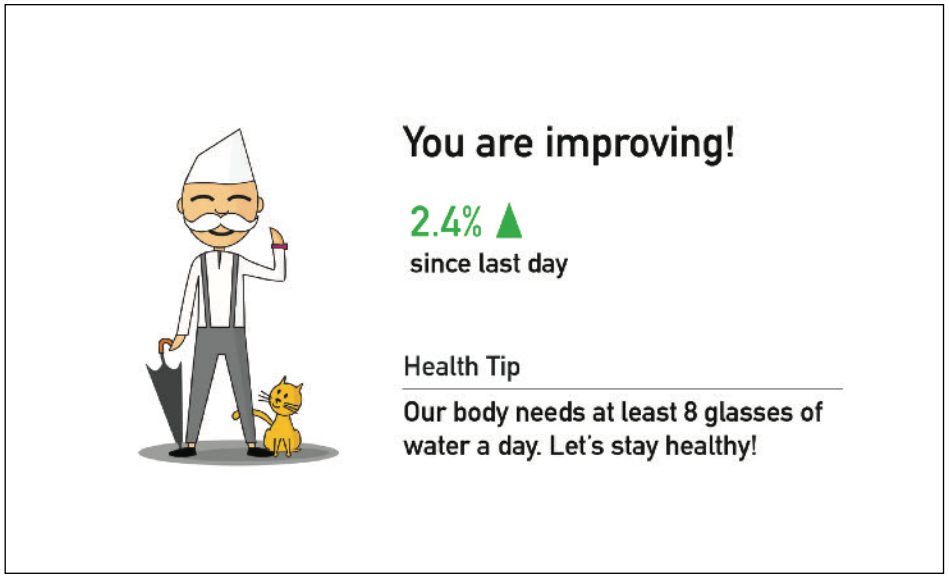
6. The completion screen - A message stating that the objective is achieved is shown upon completion (Fig. 9.14).

7. The completion screen proceeds to the Feedback Screen. Here the participant is shown with his improvement index and a health tip. This brings to the end of the session (Fig. 9.15).

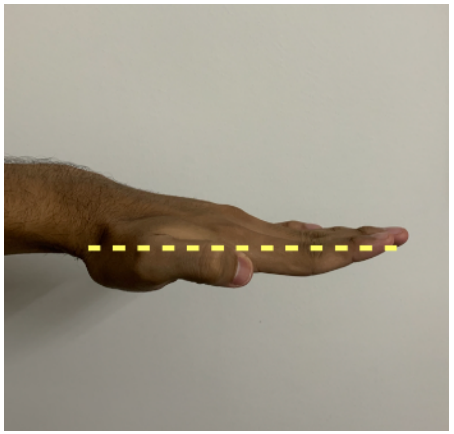
Fig 9.10. Welcome screen.

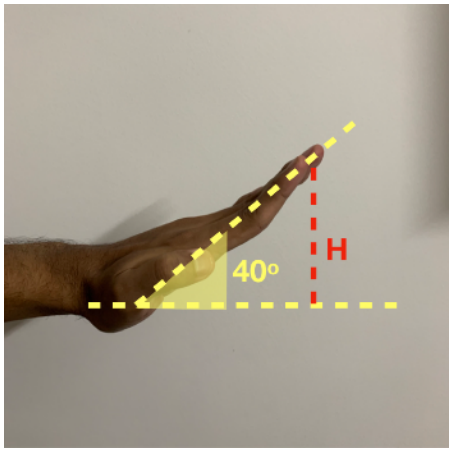
Fig 9.11. Establishing the scenario.





From top left in clockwise direction: Fig 9.12. The calibration screen. Fig 9.13. Confirmation for calibration and a free light to start. Fig 9.14. Completion screen shown once the session is completed. Fig 9.15. Feedback screen with the improvement index and health tip.

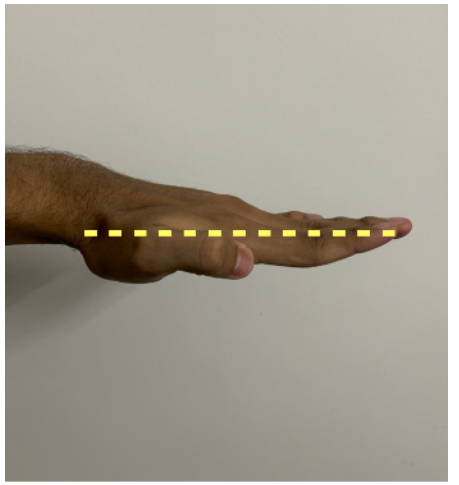


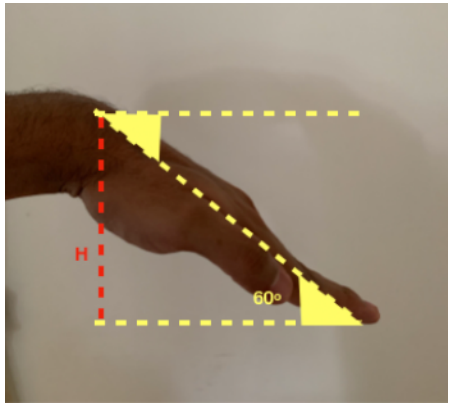


1. Jump

Category: Extension

On his way Chachaji encounters obstacles which has to jumped over or slid down. By lifting all the finger at a time keeping the lower end of palm on board helps Chachaji to jump. The higher the lift, higher the jump. Since the requirements of each patients varies, minimum height required to jump can be adjusted by the therapist according to the progress of the patient. The height (H) made by the fingers create an angle and this measurement is taken. Extension is achieved in this case.

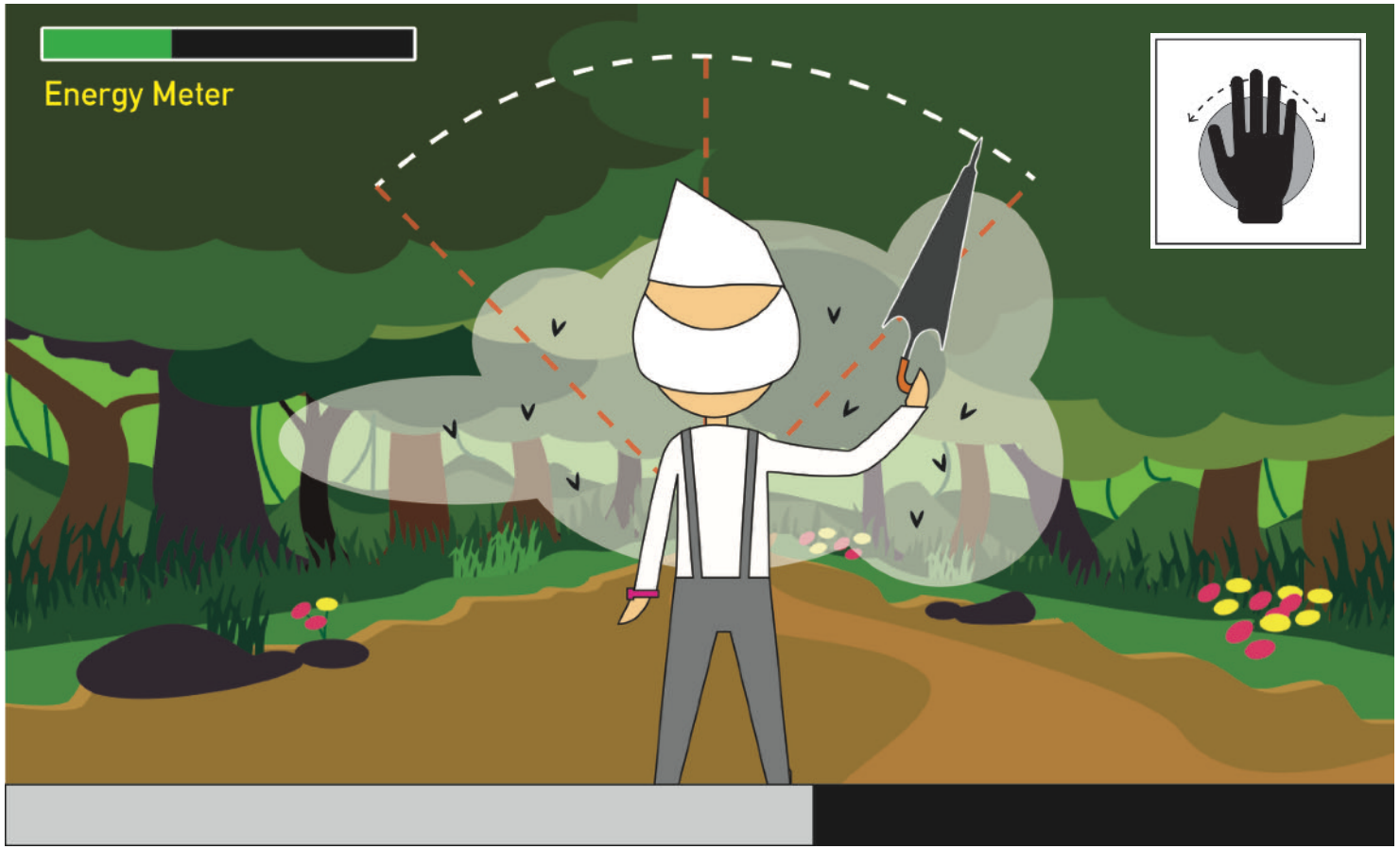


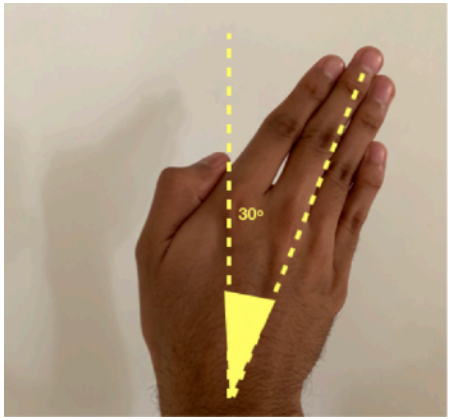


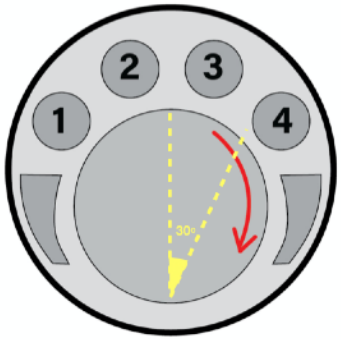
2. Slide

Category: Flexion

This time Chachaji has to slide down. By lifting the lower end of palm and keeping the fingers on the controller board helps Chachaji to slide down. The higher the lift, lower the slide. The height (H) made by the palm create an angle with the fingers and the board. This will be the same as that of the angle the palm created with the rest of the arm (alternate angles created by the line intersected by parallel lines are equal). This measurement of angle is taken for evaluation. Flexion is achieved in this case.



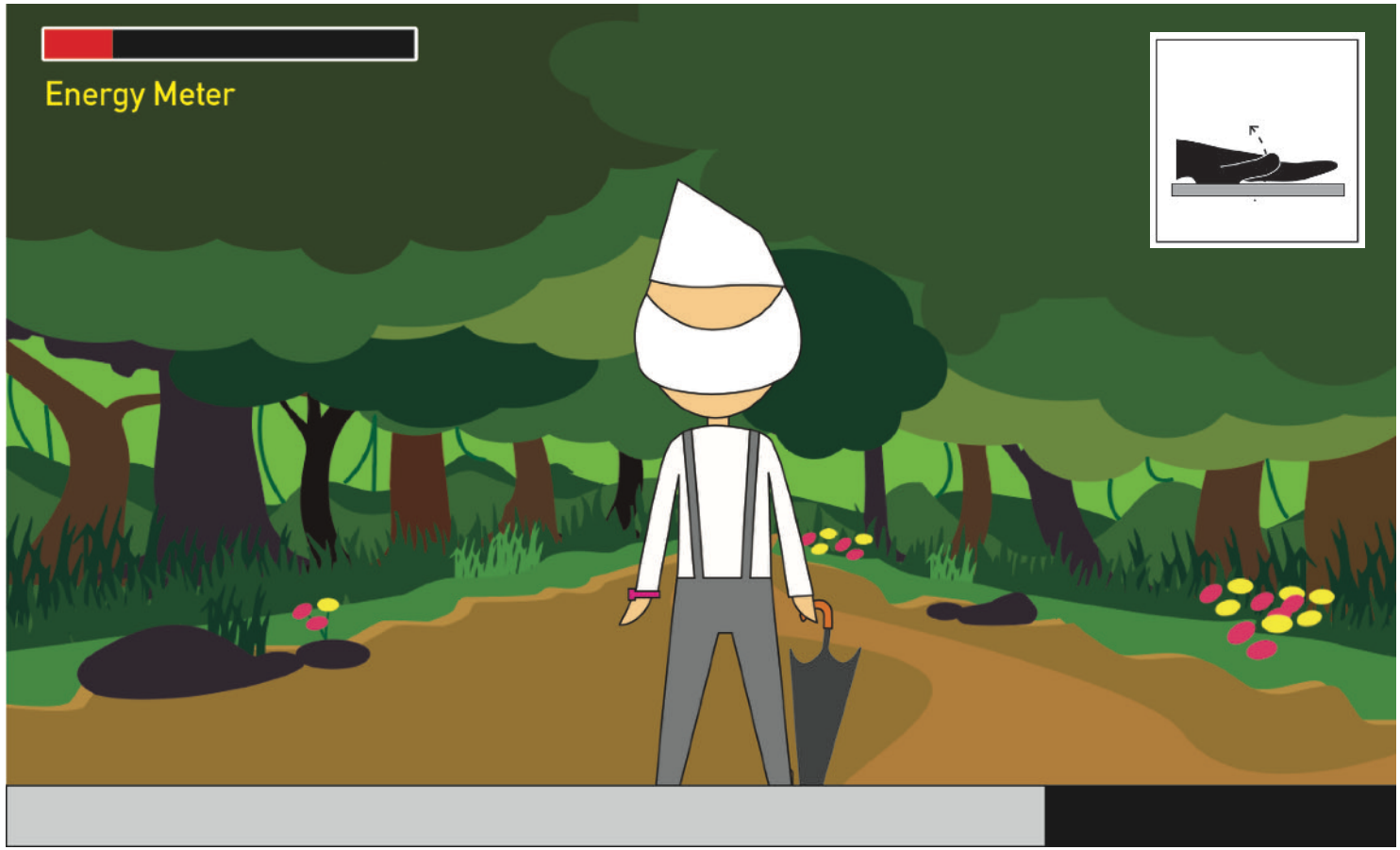


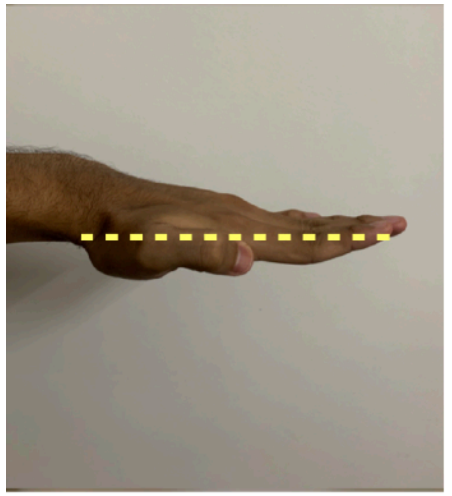


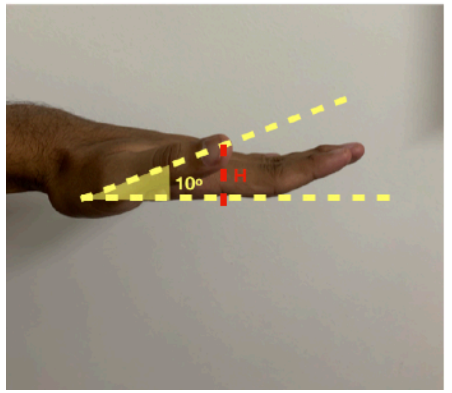
3. Wave

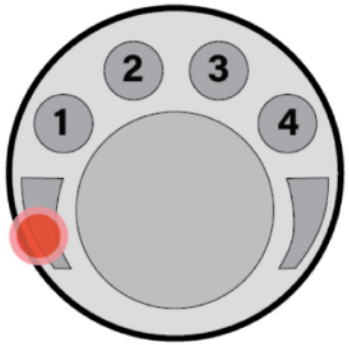
Category: Radial-Ulnar deviation

Fly swarms are a common sight in the jungle. Chachaji has to wave his magic umbrella to shoo them away. It is done with the help of the rotating disc. The disc is rotated to get the desired angle. The angle is increased with increase in level. The sensor in the controller reads the angle and is stored in the application. Radial and Ulnar deviation of the hand is achieved with this.





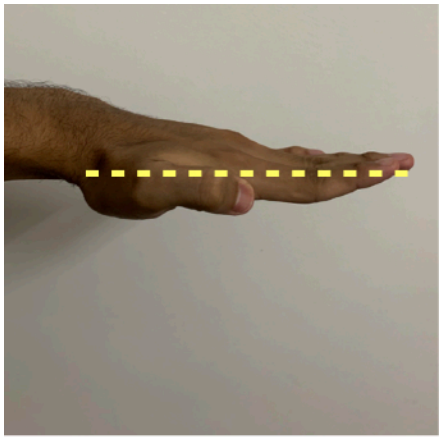


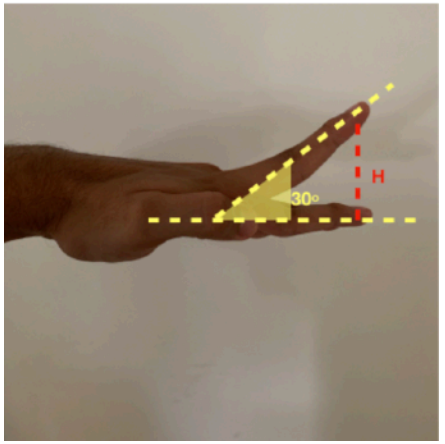


4. Power-Up

Category: Range of Motion - Thumb

It is very likely that Chachaji's energy gets drained after a point of time. Hence it is necessary to power up his energy. They energy bar is shown in the screen. Energy upgrade is achieved by lifting the thumb and taping over the thumb plate below. The angle created with the board os calculated with the distance from the board using the sensor. Higher the angle, higher the energy pumped up.





5. Open

Category: Range of Motion - Fingers

There are chances of Chottu hiding inside the boxes. The numbered boxes can be opened by lifting the fingers corresponding to the number on the controller pad (2 and 3 in this case). This creates an angle with the board and is calculated with the ultrasonic sensor on it. By knowing that distance (H) the angle can be calculated. Larger the box more the extension to opene it. The size can be increased or decreased according to the need by the therapist.

10. Evaluation

There were lot of challenges faced because of the lockdown restrictions arised due to the COVID-19 pandemic. There were limitation in users for testing. However since my grandfather who did physiotherapy for hand was home, I could do the with him with the prototype. I was unable to make a finished prototype with all the sensors due to the lack of materials and equipments due to the lockdown. But an alternate method was used to track the motion. With the help of Kinovea (ver. 0.8.25) - a motion capturing tool, the movements were tracked and measurements were taken while simulating the rest of the setup.

A four day test run was carried out with the participant and readings were taken for extension and radial-ulnar deviations (Appendix 2). Qualitative evaluation was also done to evaluate the effectiveness of the system. Sample questions include -

- Did you enjoy the game? Why?
- Was there any confusion in identifying the tasks or actions?
- Were you concerned about not being able to complete the task?
- Were you able to relate to the character?
- Do you feel your hand flexibly is getting better?
- Do you have any other suggestions?

Insights from user evaluation -

- The game was very well appreciated and enjoyed by the user.

Fig 10.1. User Testing.

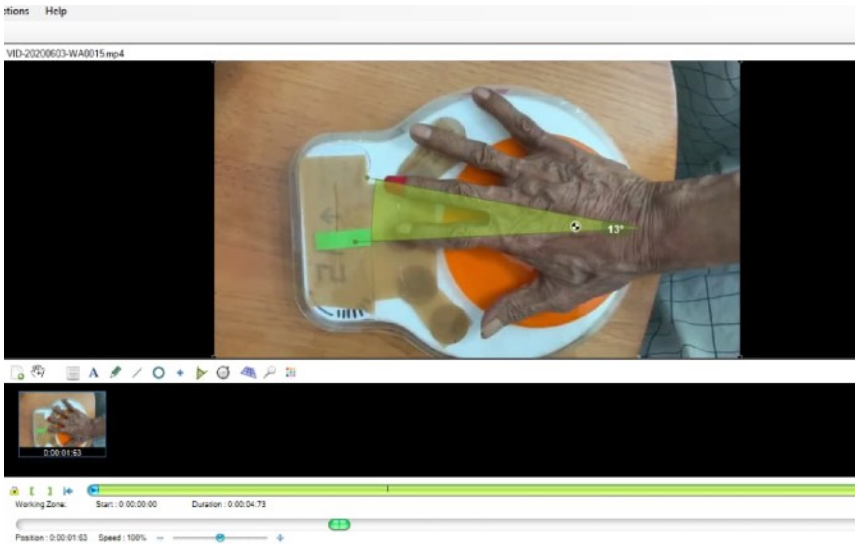


Fig 10.2. Screenshot from Kinovea (ver. 0.8.25). Fingers and prototype were given reference points for easy tracking.

- The user found it easy to use the hardware and was adapted to the system very fast. During the third and the fourth day of evaluation, the participant could remember the gesture without reference.
- The user very rarely looked at the controller while doing the exercises.
- There was an overall feeling of satisfaction with the user after every session.
- The user felt that the screen was overcrowded with objects and sometimes he could figure out the task only after close observation.
- He was concerned about the accuracy of the measurements.

Expert evaluation was also done with a physiotherapist regarding the content, the controller and the nature of the exercises over phone call after sharing the contents.

Insights from expert evaluation -

- The idea of contextualising the content to India was appreciated.
- Therapists found the idea of adjusting the requirements of the game according to the patients' need very useful.
- Considering synergistic patterns while calibration was very important and was missed in the setup.
- The early stages of the game could demand even lesser cognitive load as some patients will find it difficult.
- Fatiguability is a common problem found in elderly. Keeping breaks after a point of time maybe by continuing the story automatically for a while might help the patients do the exercise more accurately.

11. Conclusion

The positive response from the therapists and the participant from the evaluation emphasises the need and the importance of exercise gaming in telerehabilitation. Contextualising to the Indian context and a relatable character made the gameplay interesting and immersive. The simple hardware and intuitive gestures made it easy for the participant to adapt with the system. The improvement index shown at the end motivated the participant to play the game again and work harder for a better index. The freedom to adjust the requirements of the exercise according to the needs of patients and the theme of the game were very much appreciated by the therapists. The project is its early stage and has a lot of potential to make it even more affordable with more technological interventions.

Let us have a healthy lifestyle and build a healthier India!

12. Future Scope

The system has opportunity to add more games and stories by keeping the equipments same. Different games contextualised for specific target group would add more value to the product. The same system can be extended to children as an exercise or learning tool by changing the content. Introducing multiplayer games where the participants can play with their friends or relatives make it more interesting and creating a leaderboard would help them motivated to stay within the system for a longer time. Translating the contents in more languages can cater to more users. In person communication with the therapist is very important during rehabilitation. Therefore incorporating a real time video chatting and recording mechanism within the system cloud be more helpful while doing it remotely.

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Appendix

1. Alternate game ideas

- Helping Hanuman (Fig. 1)
- Finding Sita (Fig. 1)
- Quiz Up (Fig. 2.)

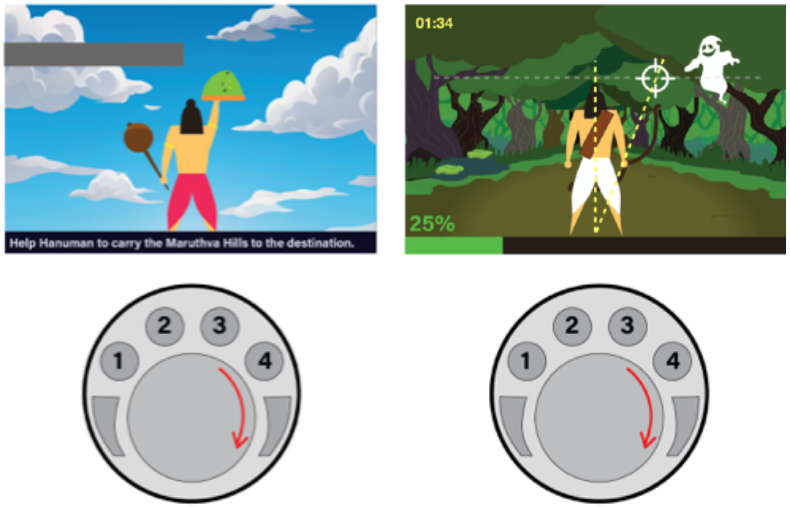

Fig 2. (left) Helping Hanuman - The game aims at helping Hanuman to carry the Maruthva hills to the destination so that the medicine is delivered on time. On his way, Hanuman encounters barriers which had to be dodged. This can be achieved by rotating the disc. The rotation of the disc is directly proportional to deviation. Radial and Ulnar deviation of the hand is achieved with this.(right) Finding Sita -This is game which narrates the story of Rama going to get Sita from Ravana. On this journey he encounters many obstacle and should overcome those. By different gestures done over the control/exercise pad, the objective can be achieved.

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Fig 2. This is an A/B Quiz where the player will be given a question and two options as answer. The player has to rotate the disc to left or right to select the answer. The answer will be uncovered according to the degree of rotation. The movement of the bar is directly proportional to the angle of rotation The bar above the choice shows the progress. The rate of increase decreases with the increase in level. Radial and Ulnar deviation of the hand is achieved with this.

2. User evaluation data

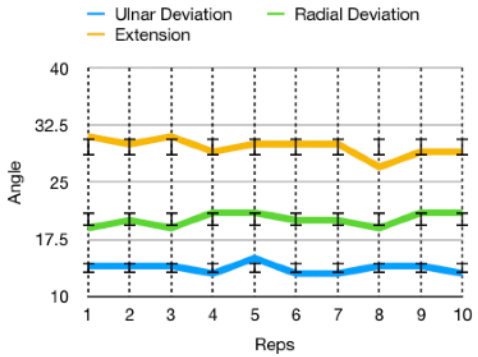
Day 1
4 June 2020

Session 1

Ulnar Deviation
Max: 15 Min: 13

Radial Deviation
Max: 21 Min: 19

Extension
Max: 31 Min: 27

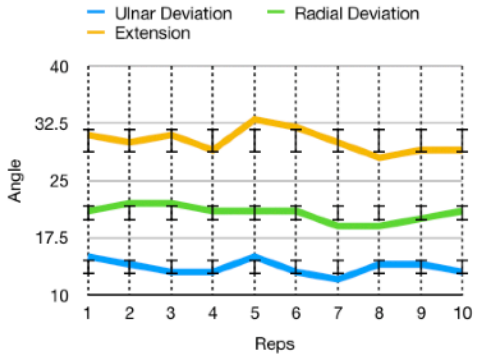


Session 2

Ulnar Deviation
Max: 15 Min: 12

Radial Deviation
Max: 22 Min: 19

Extension
Max: 33 Min: 28

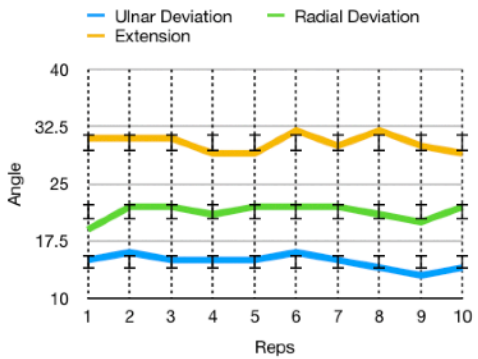


Session 3

Ulnar Deviation
Max: 16 Min: 14

Radial Deviation
Max: 22 Min: 19

Extension
Max: 32 Min: 29



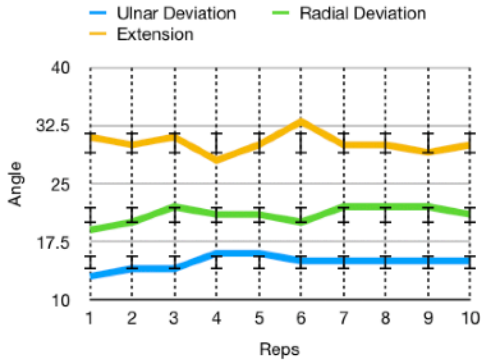
Day 2
5 June 2020

Session 1

Ulnar Deviation
Max: 16 Min: 13

Radial Deviation
Max: 22 Min: 19

Extension
Max: 33 Min: 28



Session 2

Ulnar Deviation
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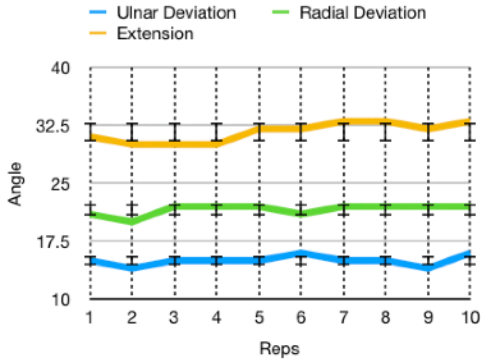
Radial Deviation
Max: 22 Min: 20

Extension
Max: 33 Min: 29

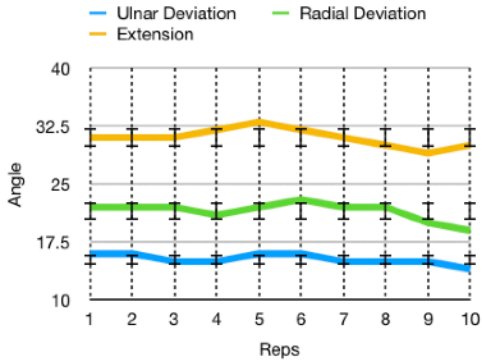


Session 3

Ulnar Deviation
Max: 16 Min: 14

Radial Deviation
Max: 23 Min: 19

Extension
Max: 33 Min: 29



Day 2
7 June 2020

Session 1

Ulnar Deviation
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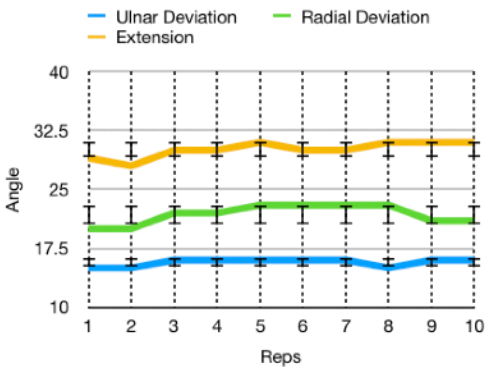
Radial Deviation
Max: 23 Min: 20

Extension
Max: 31 Min: 28

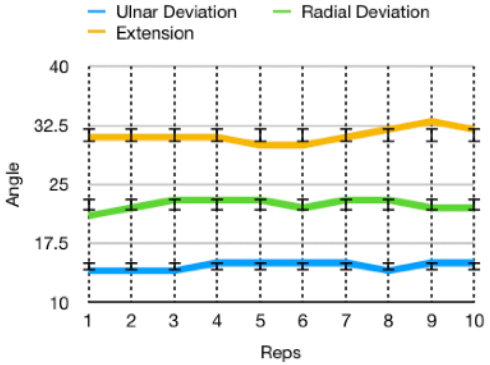


Session 2

Ulnar Deviation
Max: 15 Min:14

Radial Deviation
Max: 23 Min: 21

Extension
Max: 33 Min: 30

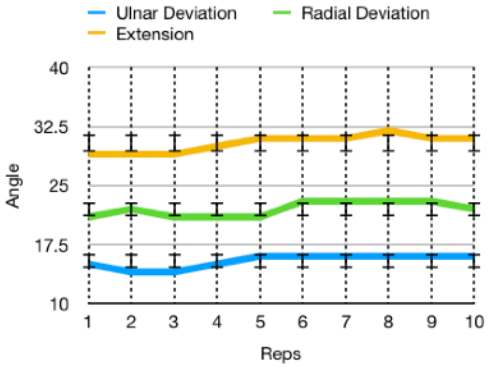


Session 3

Ulnar Deviation
Max: 16 Min: 14

Radial Deviation
Max: 23 Min: 21

Extension
Max: 32 Min: 29



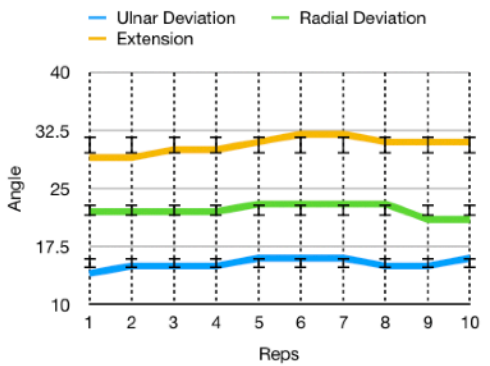
Day 4
8 June 2020

Session 1

Ulnar Deviation
Max: 16 Min: 14

Radial Deviation
Max: 23 Min: 21

Extension
Max: 32 Min: 29

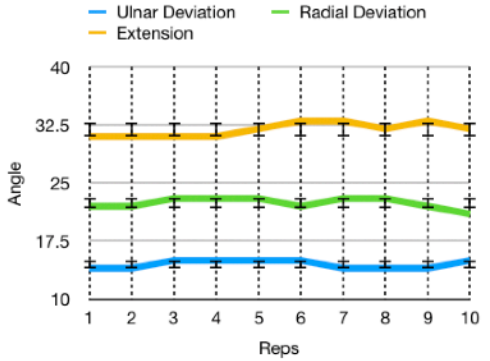


Session 2

Ulnar Deviation
Max: 15 Min:14

Radial Deviation
Max: 23 Min: 21

Extension
Max: 33 Min: 31

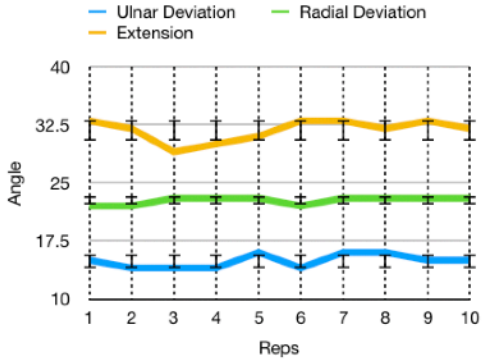


Session 3

Ulnar Deviation
Max: 16 Min: 14

Radial Deviation
Max: 23 Min: 21

Extension
Max: 33 Min: 29



Thank You!