Project 2

Smartphone based exercise game for finger dexterity - an adjunctive therapy app for stroke patients

Submitted in partial fulfillment of the requirements of the degree of Master of Design by-

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Approval Sheet

The Interaction design project II entitled "Smartphone based exercise game for finger dexterity - an adjunctive therapy app for stroke patients" by Angela R. Simon, roll number-176330010 is approved, in partial fulfillment of the Masters in Design Degree in Interaction Design at IDC School of Design, Indian Institute of Technology, Bombay.

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Abstract

Stroke is a medical condition that can leave a person physically and cognitively impaired. It is possible to regain the lost functionality through repetitive exercises that help in retraining the brain. Post-stroke rehabilitation can extend from months to years and it demands motivation and a disciplined exercise routine in order to achieve the recovery goals. Games have been used to transform these repetitive exercises into fun engaging activities during therapy.

This project is focused on the use of smartphones for delivering exercise routines at a low cost and accessible manner. We present the design of an exercise game for finger dexterity that can be played by stroke patients on a smartphone as an adjunct to treatment, alongside visits to the therapist. Apart from converting finger exercises into game controls, the design of the game also helps patients maintain an exercise routine as well as motivate them to take charge of their recovery pace. The primary game mechanics was prototyped and evaluated for its feasibility by an expert therapist. The feedback received were used to develop the game further. The final design has been presented in this report.

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2 Introduction to stroke rehabilitation

Stroke or brain attack is caused due to lack of blood flow in certain part of the brain. This could be due to a vessel getting blocked by a blood clot that travelled up or rupture of a blood vessel that results in a hemorrhage. When a block occurs in a blood vessel, the cells that do not receive blood start dying. As a result, the brain loses control of the body parts that were linked to the affected areas. The chance of surviving a stroke depends on the severity of the stroke and the patient's age [1]. If the stroke is severe, it can prove to be fatal and cause death within a period of 3-4 weeks. If the patient survives it, he or she will be left with cognitive and physical impairments of the affected parts.

Hemiparesis is one of the after-effects of stroke that is characterized by weakening of the complete one side of the body. Hemiplegia is a more extreme form of hemiparesis which is the complete paralysis of the affected side of the body. It has been reported that almost 80% of stroke survivors are left with hemiparesis, making it one of the most common side effects [2]. A patient can be either right or left hemiparetic based on the side of the brain that suffered the attack. In this project, we have studied hemiparetic patients of stroke.

2.1 Post-stroke rehabilitation

As mentioned before, the loss of motor functions after stroke is due to the death of brain cells that were responsible for these functions. Neuroplasticity is an ability of the brain that allows it to reorganise itself to compensate for the damaged parts. The functions that were once carried out by the affected parts can be taught to the unaffected parts of the brain and thus,

the patient can regain the lost functions. One of the ways to trigger this ability of the brain is through large repetitions of physical exercises that recreate the neural pathways for motor control. Post-stroke rehabilitation is therefore planned with exercise routines that help the patient re-learn motor skills by repetition. The earlier a patient starts physical rehabilitation the better the chances for recovery. As the patient begins recovering after stroke, the various stages of recovery are identified using the Brunnstrom approach [3].

2.2 Brunnstrom stages

Movement in the human body is a result of complex coordination between multiple muscles. This collaboration of muscles to produce a normal movement is termed as muscle synergy. After suffering a stroke, the muscles of the affected side of the body become flaccid. As a patient starts to recover, abnormal muscle synergies tend to develop due to spasticity, muscle weakness and poor coordination. The Brunnstrom approach is used by the therapists to identify these developments as they appear and use the reflexes and synergies to train the patient towards gaining voluntary muscle control.

According to Brunnstrom, there are 6 stages of recovery —

Stage 1 - Flaccidity
Immediately after the stroke, the patient is left with flaccidity on the affected side with no movement occurring in the limbs and zero muscle activity.

Stage 2 - Synergies and some spasticity
Depending on the brain functions, the patient starts to show little muscle activity in the form of

spasticity, reflexes and synergy movement patterns. This is the onset of the recovery phase after stroke.

Stage 3 - Marked spasticity

At this stage, the patient shows more pronounced spasticity and stronger obligatory synergies. The patient has gained some amount of voluntary muscle control through synergy pattern.

Stage 4 - Out of synergy/ less spasticity

Patient movements may be out of sync with muscle synergy but spastic muscle movement will reduce. Controlled movements are still difficult.

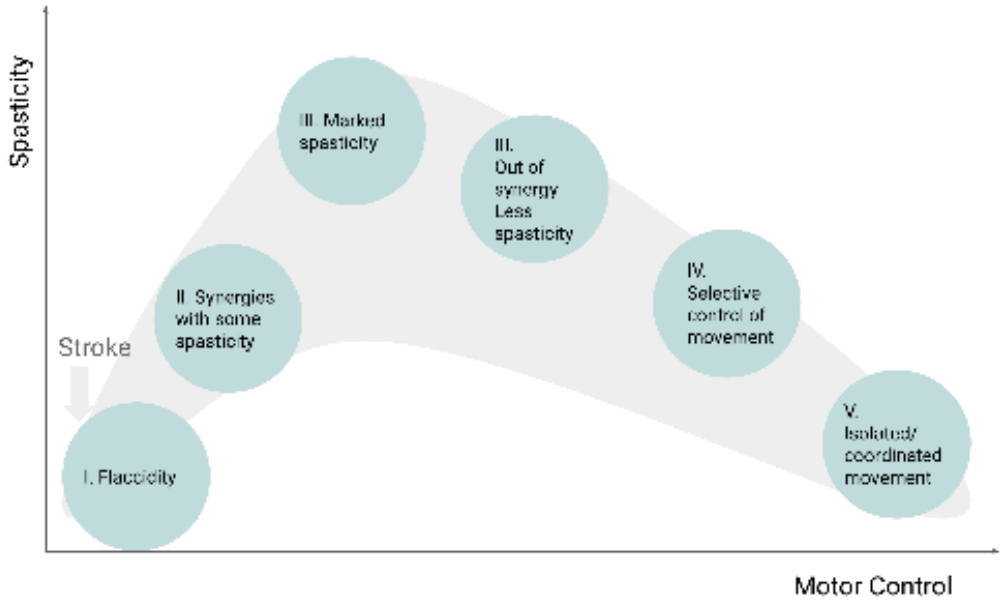


Figure 1: Brunnstrom stages of recovery after stroke

Stage 5 - Selective Control of movement

Patient is able to perform voluntary movements with increased complexity. Spasticity reduces significantly and the synergy patterns are less visible in a patient's movements.

Stage 6 - Isolated/coordinated movement

Spasticity at this stage disappears completely and the patient is able to perform near-normal to normal movements with better coordination. Synergy patterns return to their normal state from this stage onwards.

2.3 Muscle weakness and strength training

The severity of muscle weakness can be classified into different "grades" based on the following criteria [4]—

Grade 0: No contraction or muscle movement.

Grade 1: Trace of contraction, but no movement at the joint.

Grade 2: Movement at the joint with gravity eliminated.

Grade 3: Movement against gravity with no added resistance.

Grade 4: Movement against gravity with mild resistance.

Grade 5: Normal strength, movement against gravity with complete resistance.

The exercises to develop muscle strength are based on this scale. When a muscle has to be trained, the therapist first deals with reducing spasticity at Grade 1. The affected muscle is also unable to initiate activity on its own during the early recovery stage. This is overcome by applying electrical stimulation to the muscle which assists the patient to initiate movement. As patient gradually develops muscle initiation ability, exercises with varying strength requirements are practiced.

The patient first tries to do exercises with no added resistance of any form as the muscle strength at this stage is very low. These exercises are performed in a gravity eliminated condition which could also be in the form of assisted/supported movement during the exercise.

The next stage is to perform the exercises against gravity. The patient should be able to display enough muscle strength to lift a body part off a surface following which the patient is to perform exercises against some amount of resistance that is externally applied. The patient may use theraband and theraputty for such exercises. The therapist may also use weight cuffs that are attached to the body part as added resistance during exercise.

3 Game based-interventions in physical rehabilitation

The primary reason for introducing games in physical rehabilitation is to enable the patient meet the sufficient number of repetitions through game play [5]. Games keep the patient engaged and motivated. Most of the games designed for physical exercise are based on motion capture which is carried out by various hardware and software extensions like motion capturing sensors, and cameras capable of motion sensing.

Various systematics reviews have revealed some of the popular trends in game-based interventions for physical rehabilitation [6,7]. An overview of different technologies used has been listed below.

3.1 Off-the-shelf technology

Popular gaming consoles that have hand-held controllers with motion capturing sensors (Figure 2) are a convenient option for game-based rehabilitation. Commercially available exergames are tweaked to meet the requirements of the patients.

Games based on image recognition for motion sensing have been another popular choice. eg. Kinect. The added benefit of these games is that the patient is not restrained by any device attached to the body and is free to move within the camera's field of view. The limited field of view of the camera can be a disadvantage for some types of exercises.

Virtual reality headsets in combination with motion sensors are another attractive option that

Figure 2: Wii-remote
(Image source: Wikimedia)

can increase motivation through enhanced immersiveness.

3.2 Custom made technology

Devices and hardware designed specifically for use in physical rehabilitation come under this category.

Robotics for physical rehabilitation provides options for assisted movement training. Mechanical splints and exoskeletal devices that provide real-time feedback on a screen help the patient to understand their movements better and improve during the exercise. Specially designed electro-mechanical devices used in combination with a computer game have been used for exercising. Wearables (Figure 3) that can be strapped on to the body are another option for some exercises.

Figure 3: Music Glove by FlintRehab (Image source: flintrehab.com)

The games that are designed with such devices have very specific applications and goals that have been identified uniquely for the target patients.

4 Primary Research

Primary research was conducted in order to understand rehabilitation of stroke and identify opportunities for low-cost game-based interventions that can be introduced in existing protocols with ease. Understanding the landscape and ecosystem involved studying a rehabilitation center and deriving insights from interaction with therapists and patients.

Adult-Neuro rehabilitation at Nair Hospital

We studied the physiotherapy centre at Nair Hospital. The therapy centre (Figure 4) functions under a government academic institution and provides free physical rehabilitation to its patients.

Stroke rehabilitation is provided in the adult-neuro rehabilitation section. It caters to adult patients with physical disabilities associated with neurological medical conditions. The facility is equipped with the most basic requirements and equipment for exercise. These include cycling pedal for foot, balance foams, gym ball, therabands and theraputty, a life-size vertical mirror, electrical stimulation equipment, weight clutches, pegboard, rubber and plastic balls - the size of a football or basketball, marker cones etc. No other exercise equipment were found in the facility.

Physical rehabilitation at this centre was focused on exercises that didn't require additional equipment. The goals of the exercises were strength and muscle building alongside coordination. Since the exercises required no additional equipment, patients are often instructed to practice the same routine in their homes too. The appointments are set for three

Figure 4: Physiotherapy school and centre Nair Hospital, Mumbai Central

times a week every alternate day and a session lasts for 45 mins max. Each exercise is done with 10 repetitions on an average.

Table 1: A list of few of the exercises for Hemiplegic/Hemiparetic patients at Nair Physiotherapy center

Hemiplegia (Bridging)	**Lower Limb**	**Upper Limb**	**Balance**	**Gait Training**
Pelvic Bridging	Sit to Stand	PNF pattern	Stepping activities	Obstacle walking
Unilateral Bridging	Lunges	Weight bearing inside sitting	Foam Standing	Back walking
Bridging with ball	Mini Squats	Pegboard	One leg stance	Side walking
Bridging medial and lateral roll	Toe Standing	Theraband exercises*	Close standing	
Knee roll with the ball	Dynamic Quads with weights		Tandem standing	
Ball push against the wall	Abductor strength		Marching	
Quadruped - hand raise, leg raise, alt hand and leg raise	Prone knee bending			
Kneel walking - forward & backwards				
Kneeling - reach outs				
Half kneeling				
Quadruped - weight lift				

4.1 Insights on a cost-effective treatment approach

During contextual inquiries with the therapists at the centre, we found that most of the exercises given to the patients could be done at homes with ease. The therapists also suggested ‘do-it-yourself’ methods for the other exercise props they used in the centre. For example, cone markers (Figure 5) could be replaced by metal glass used in kitchens, theraputty could be replaced by dough, weights could be replaced by a bottle filled with some water etc. If the patient had trouble with releasing a palm grip, the therapist would ask the patient to try the same at home while dipping the affected hand in a bucket of water. The therapists in the centre were well versed with giving doable instructions for practicing the same exercises at home. On conversing with the patients there, it was found that they found this approach very helpful and it kept them motivated to keep trying the exercises at home. We found that this empowers the patients and helps them to not be dependent on the facilities provided by the center but take charge of their recovery process even while they are at their homes.

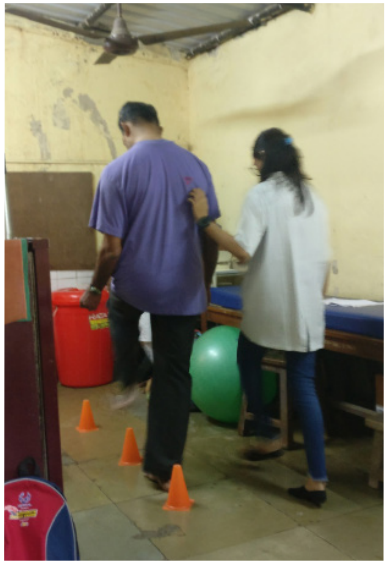


Figure 5: Patient undergoing gait training with cone markers

Another insight that came from contextual inquiry was that the patients require good feedback in the form of visuals, sounds or tactile sensation while doing exercises. The current play tools (Figure 6) for practicing grips are able to provide only tactile sensations.

Figure 6: Activities for the hands

Also, the therapists stated that most of the gross motor skills could be recovered conveniently with the exercise routines taught at the therapy center. It is the fine motor skills that required more efforts from the patients side as they take time to develop again. Most of the activities of living are carried out by the hands. Through it, we can eat our food, comb our hair, carry out personal care etc. After a stroke, the hand can become immobile and inarticulate. Fingers

stiffen up and the wrist doesn't function in a controlled manner even after the recovery has begun.

One of them most distressing losses in a stroke is the use of hands. Although the person may be able to resume walking, they find that they can't coordinate actions in the fingers of the hand because the fingers are particularly requiring more finer control. This can be frustrating to patients as some of them may not be able to carry out activities of daily living despite the overall recovery.

From these insights we further narrowed the scope of our project to developing a low-cost home-based solution for developing hand functions relevant to fine motor skills. In order to be able to include visual and audio feedback to our design solution, we decided to choose smart phones as an accessible medium to deliver interactive experiences while exercising the hand.

4.2 Rehabilitation of the hands

Before deciding which hand exercise could be gamified, we tried to understand the different aspects of rehabilitating the hands. The three milestones that a therapist must cross while rehabilitating the upper limb of the patients are as follows [8] –

1. Can the patient produce any voluntary muscle activity in the affected upper limb?
2. In the seated position, can the patient produce any shoulder abduction against gravity?
3. With the forearm prone on a table and the hand and fingers unsupported, can the patient initiate finger (and/or thumb) extension three times within a minute?

At every stage, the therapist provides treatments and exercises that are for strengthening

the targeted muscle groups. The therapist also looks for patterns of movement that are unnatural and corrects them. The finer control of the fingers is regained at a very later stage during rehabilitation. As mentioned earlier, it is mostly the case that the patient will be able to walk and produce a basic range of motion movements but may still face difficulty in performing fine isolated movements with the affected hand. The third milestone of being able to perform finger extension three times within a minute is possible only at a stage where the patient has regained the control of the smaller muscle groups in the hand.

Functions of the hand are of 4 types –

1. Reaching
2. Grasp
3. Release
4. Manipulation

Treatment implementation for different Brunnstrom stages of the hand [9]

Stage 1 and 2 - Achieve mass grip and wrist fixation

Stage 3 and 4 - Forearm pronation and finger extension is facilitated.

Stage 4 - Patient pulls the thumb away from index finger. Exercises for further control of thumb movement. Functional use of lateral prehension is encouraged. Eg. Holding cards, using a key.

Stage 5 - Advanced prehension patterns are encouraged through different activities. The increasing order of difficulty is as follows - palmar prehension, cylindrical grasp, spherical grasp.

Stage 6 - Patient is encouraged to be able to do individual finger movements. Home program

of activities to encourage individual finger use, speed and accuracy is provided.

Different tasks and activities for manipulation and dexterity practice [9] include –

1. Tapping tasks like touching each fingertip to thumb in sequence within a given time and tapping the table with single fingers
2. Cupping tasks like scooping coins from table to palm of hands. This is to train opposition of radial and ulnar sides of hand
3. Picking up different objects between thumb and fingers
4. Picking up objects of varying size and weights from one place to another.
5. And more difficult tasks of typing on a computer keyboard, tracing a circle without touching the lines, walking with a glass of water, opening door handles etc.

4.3 Smart phones for exercises of the hand

To decide upon the most suitable exercise that could use smart phones for an interactive exercise experience, we explored the various ways a person could interact with the device (Figure 7). The dimensions and the weight of the device was also considered to assess ergonomic comfort of the interaction from the perspective of a stroke patient.

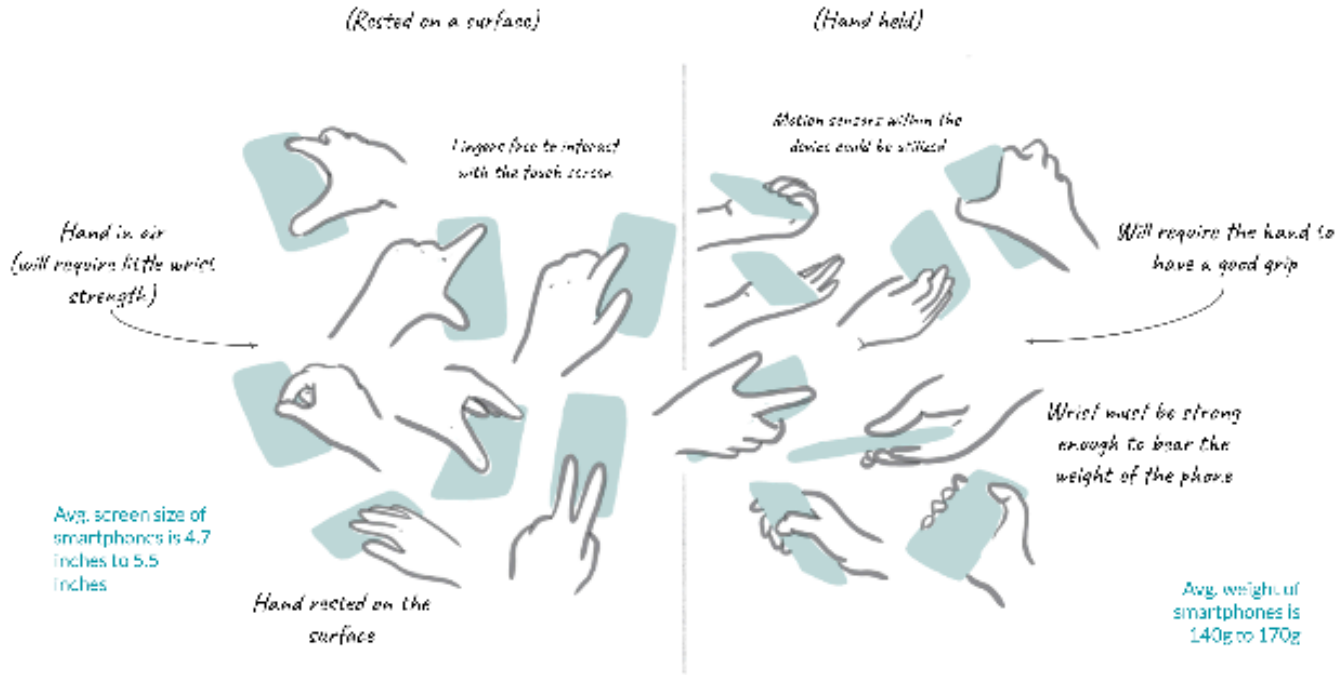


Figure 7: Explorations on various hand positions and grips with a smartphone

Insights for design direction

Majority of the patients in the studied population were at a stage where they had enough strength to hold objects placed in the affected hand but faced difficulty in grabbing and releasing them on their own. Their recovery stage can be mapped between Stage 3-6 of the Brunnstrom stages for the hand.

Grabbing requires finger extension and thumb opposition first so that the patient is able to wrap the fingers around the object to obtain a perfect grip. Holding the object involves wrist and finger flexion. In order to release the object, the patient must be able to do wrist extension, finger extension and, thumb abduction and extension. Being able to do the above will allow the patient to perform different grasps and prehensions with objects. Manipulating an object will further require independent finger flexion and extension at the individual MCP (Metacorpophalangeal) joints. Since most of the patients had problem releasing their grip, we understood that they reuired exercises that must stregthen their individual fingers.

Referring to the explorations (Figure 7) we had done on the various ways of interacting with smartphones, the most suitable exercise that could be gamified on smart phone were found to be those related to the fingers i.e. finger flexion, finger extension and thumb opposition

4.4 Pilot study on use of touchscreen devices for hand exercises

Touchscreen tablets have been used earlier as a medium for exercise applications like Dexteria and ReHand (Figure 8). These apps have been specifically designed as adjunctive therapy applications for improving hand dexterity. However, considering our study population, affording a digital tablet for using such applications at home is impractical. Our solution of using smart phones instead of a tablet, addresses the challenge of designing a similar interactive exercise app that has be adapted to smaller screen size.

Figure 8: Dexteria (above) and ReHand (below)
Image source: Google playstore

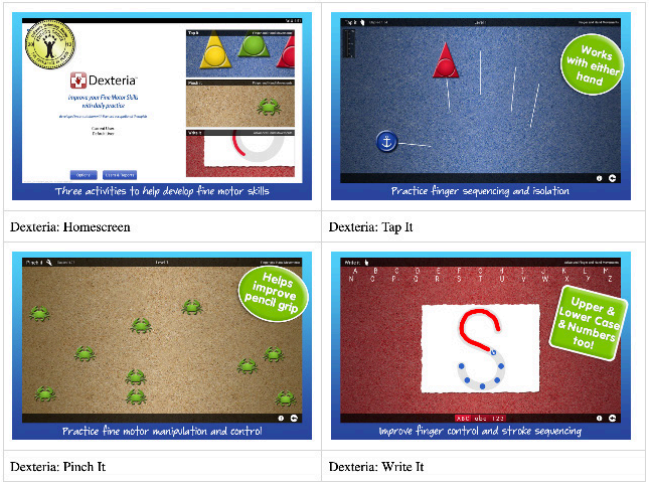
Before designing an exercise app for smart phone, we decided to conduct a study to understand the acceptance of digital tablets and games as adjunctive therapy tools amongst our patient group. Most of the patients in the study population never had previous interactions with such technology and were not tech savvy.

In our study, we observed interactions between the patient and the therapist upon introduction of a touchscreen tablet for hand exercises. The patients were asked to use two tablet applications – Dexteria and Flow Free. Both applications have been used for exercises aimed at dexterity and flexibility of the hands [10].

The two applications introduced to the participants are listed below.

1. Application 1 (Dexteria) is a tablet application for improving fine-motor skills and was developed in consultation with licensed occupational therapists (Figure 9). The application had 3 activities in it – Tap It, Pinch It and Write It.
2. Application 2 (Flow free) is a puzzle game for touchscreen devices (Figure 10). The game has been considered an effective exercise game in different game-based rehabilitation

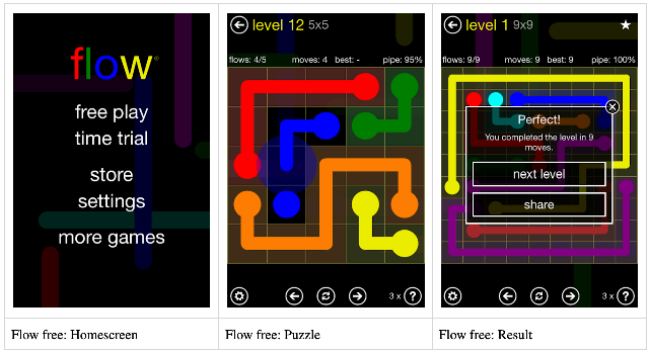
studies. The player action of joining two same colored dots by using the index finger requires a basic amount of finger dexterity and hand control. In all, there were 4 games/ activities that were given to the participants.



Dexteria: Homescreen | Dexteria: Tap It

Dexteria: Pinch It | Dexteria: Write It

Figure 9: Dexteria application for tablets
Image source: Google playstore



Flow free: Homescreen | Flow free: Puzzle | Flow free: Result

Figure 10: Flow free game on tablet
Image source: Screenshots

Insights from pilot study on use of tablets for hand rehabilitation

Our study combined field observations and semi-structured interviews with adult-neuro patients (N=7) to present the results of a qualitative analysis of the interactions between patients and therapists during the game-based rehabilitation sessions.

Analysis of the qualitative data indicates that an understanding of the deeper intrinsic motivations of a patient and the way therapists harness these motivations must also reflect in the design of therapy apps in order to encourage their independent use for long term. The major motivation for a patient to continue in rehabilitation is the desire to get back to the life they previously had and they measure their improvement based on what they could normally do before. We observed that majority of the patients were neither familiar with using technology nor were they frequent players of casual games. Also, the applications used in therapy have been mostly activity based. They are not necessarily games. Patients find such applications repetitive and boring despite the real-time feedback and interactive visuals.

The findings suggest that it is important that the patients identify value in such an application so that they use it habitually as part of their exercise routine. When designing an exergame for the adult-neuro population, one way of bringing such adherence to an exergame application is by designing the game with goals that are task oriented and can help them measure their improvement visibly. The engaging nature of the application is useful in the rehabilitation for massed-practice but that is not enough to keep the patient motivated to use it.

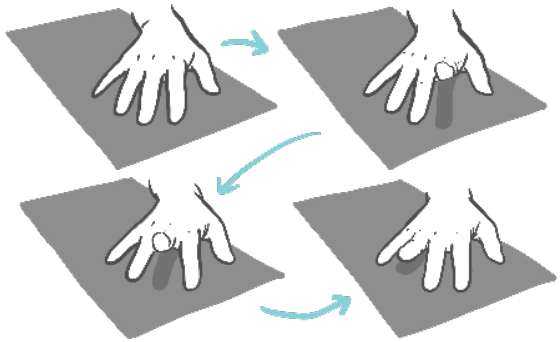
5 Design Concepts

Two finger exercises were explored while designing game concepts. They were —

1. Touching the tip of each individual finger to the thumb
2. Resting the palm on a surface and tapping the surface with each finger

The first exercise is similar to the pinch gesture that is popularly used as for interaction with touch screens. The game must have some mechanism and game play that made the user to perform the pinch gesture with all the individual fingers and not just the index finger and thumb. The gesture involves thumb opposition and movement at the MCP (Metacarpophalageal) joints of each finger.

The second exercise involves just the fingers and not the thumb. Tapping the surface with individual fingers is similar to a tap interaction on the touch screen device. However, since there are four fingers involved in the exercise, we decided to explore the multi-touch recognition feature of smart phones to design game concepts that can recognize the individual action of all the four fingers.



While designing the game concept, careful considerations were given to players average age group so that the game themes appeal to their interests. The average age group of our players would be middle-aged men and women, and above.

5.1 Game Concept 1

Pinch the dice number to move ahead in the game.

The touch control mechanics (Figure 11) involves pinching in the correct time to obtain the desired number.

The game mechanics can be applied for turn based multi-player game for eg. Ludo and Snake & Ladder. The player then exercises till the end of the game.
Game genre: Adventure, Arcade
Graphics: 2D

Pros: Since games like ‘Ludo’ and ‘Snake and Ladder’ are already well known and popular casual games on the mobile phone the familiarity and the casualness of the game can be the motivating factor for game play.

Cons: The control machanics does not depend on which finger the player uses. Chances are that the player may always use only the index finger and thumb.

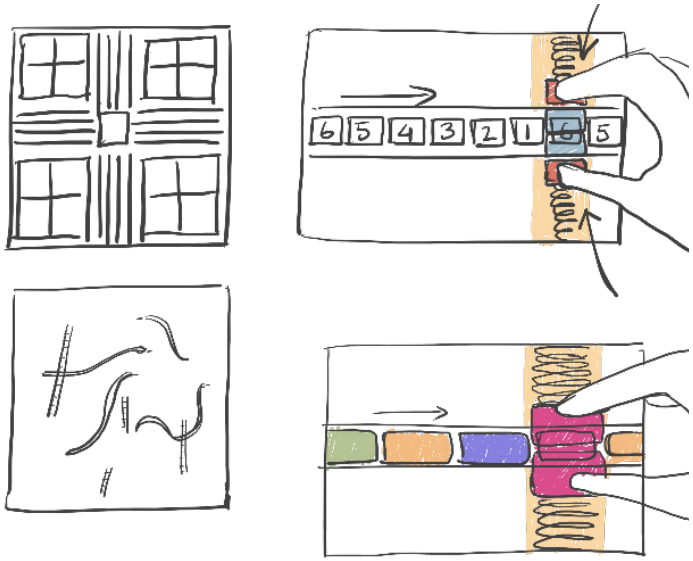
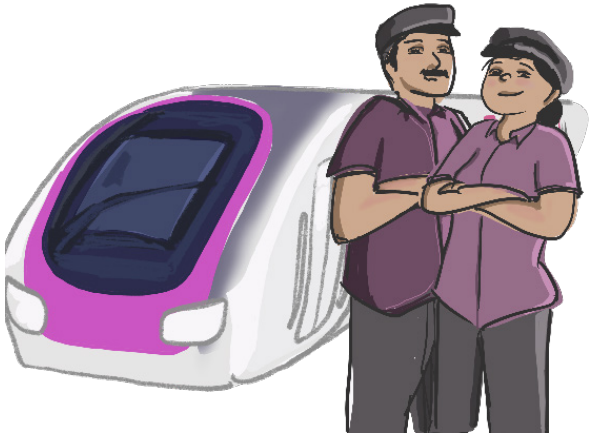


Figure 11: Pinch the dice

5.2 Game Concept 2

Pinch to open and close the door.



Gameplay: Mumbai Metro needs you! Help the train master close and open the train door for the passengers at the right time. Complete local journeys to earn coins and upgrade your train. Unlock new destinations. Make sure you keep up. Passengers will increase with time. With power comes great responsibility!
Game genre: Adventure, Arcade
Graphics: 2D

In the current level shown in the Figure 12, exercise is administered by 3 repetitions per stop. Difficulty is increased by increasing the no. of boogies, introducing time limit and increasing the speed of the game.

The game story has been intentionally set inline with a Mumbaikar's daily habit of commuting in local railways. Since most of the patients come from places away from the therapy centre, rail commute is part of their rehabilitation experience as well their regular lives. Even if a patient may not be a daily commuter, we designed the game to still draw interest with its game map (Figure 13) resembling to the real rail map. Game play could even allow the player to memorize the station names in the order of their arrival.

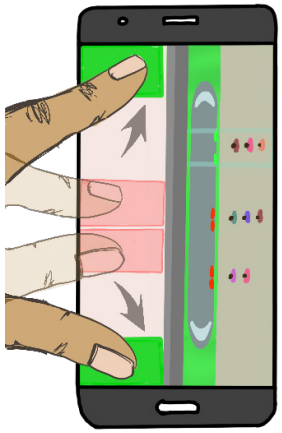


Figure 12: Pinch to open and close the door

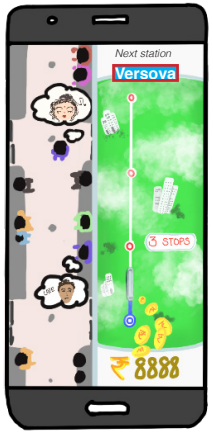


Figure 13: Game Map

5.3 Game Concept 3

Pinch fast enough for the best hairstyle.

The player pinches to get the best Bollywood hairstyle for the customer.
Difficulty is increased by increasing the no. of pinches for special hairstyles.

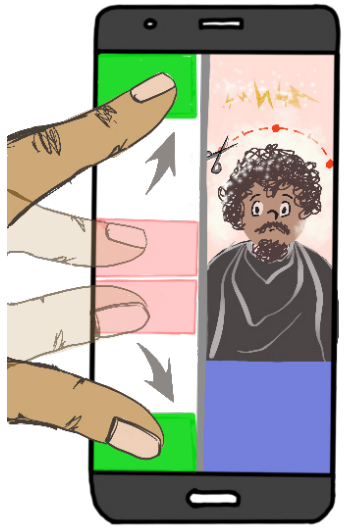


Figure 14: Pinch to make the scissors do their work

Game Play: Mumbai is known for its Bollywood style and paparazzi. Getting a Bollywood style haircut from a local barber is the theme for this game. Whether or not the player is that confident to actually go out there and get a flamboyant haircut, this game will surely bring back the memories of the 90s popular Bollywood culture.
Game genre: Simulation
Graphics: 2D

5.4 Game Concept 4

Lift your fingers to process the food order for your customer.

The patient rests the fingers on the screen (Figure 15) and lifts them individually to tap, allowing game play. Difficulty is increased by increasing the no. of orders and randomizing the order of the ingredients.

Gameplay: Your stall is attracting customers. Hurry up and process the orders fast. Stack the ingredients in the order that they appear for a perfect score.
Game genre: Arcade
Graphics: 2D

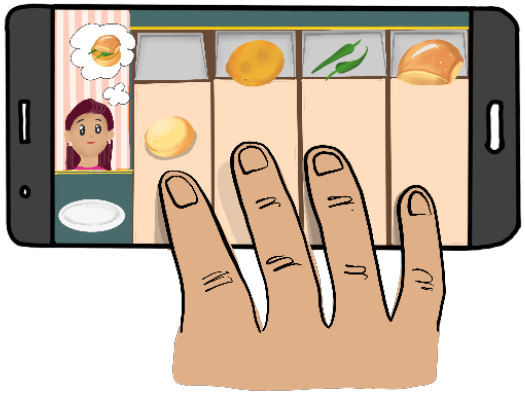
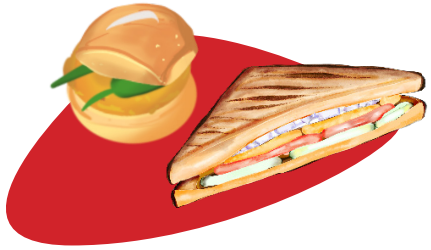


Figure 15: Tap the correct food item to stack them in correct order

Food always has a way to everyone's tummy and then the heart. This game is to feature some of the most delicious snacks from the streets of Mumbai. The variety of food items is the key to maintain interest in the game.



5.5 Final concept

The final concept chosen was the fourth concept on stacking food items and feeding the customers. A large variety of food items was seen as a good option to build more content for the game over time. This would also allow us to build a game story that is light and casual and deals with a topic that anyone can connect to. Having interesting and new content frequently was considered a must-have for designing an exergame app that must retain the interest of the patient for more than a couple of months.

In terms of game mechanics, we chose finger extension to be the exercise we would focus on. The multi-touch feature for a game control (Figure 16) was considered for mobile game design.

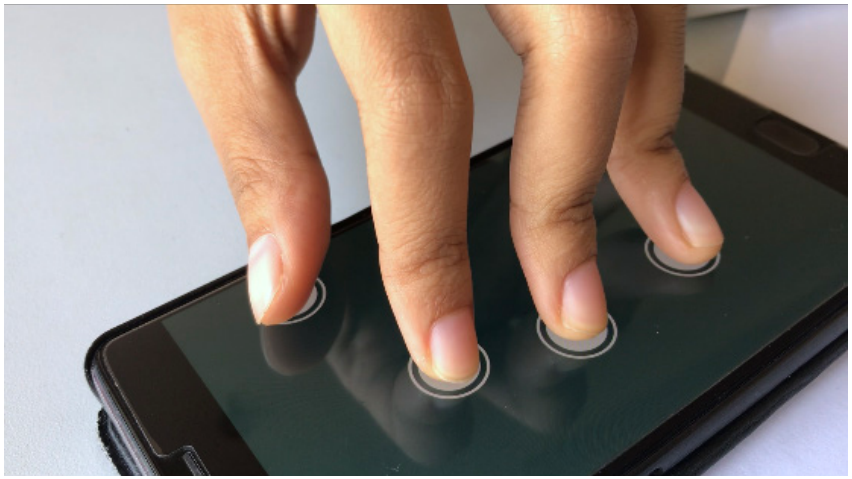


Figure 16: Multi-touch recognition on smartphone

6 Prototype

The primary touch control for the game was prototyped using Unity Game Engine. This prototype featured the main scene from the game and only one food time for stacking.

Features of the Prototype –

1. The app starts with the instruction to place your fingers one by one on the slots visible on the screen (Figure 17).
2. As soon as the game detects that all the four fingers are placed on the screen the game starts and the food items are instantiated at a random order (Figure 18).
3. The player must then tap the fingers in the correct stacking order for the food items.
4. If the person taps the wrong finger the device gives a haptic feedback in the form of vibration and the correct food item blinks to indicate the player which finger she must tap.
5. For a stroke patient it may be difficult to lift just one finger at a time independently. Chances are they one or more fingers may be raise along with the intended finger. This according to the exercise requirements is an error. In the game this error is detected when 3 or more fingers are off the screen. The game is paused (Figure 19) and the player is requested to place the fingers back on the screen one by one to resume.
6. A point is added to the score when the player completes stacking the food item in the correct sequence.

Figure 17: Start Scene

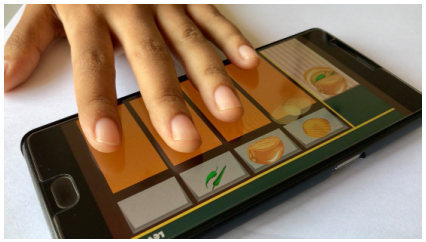


Figure 18: Food items being placed on the trays

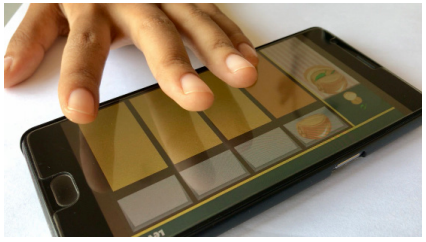


Figure 19: Game pauses and the screen goes grey.

6.1 Feasibility testing with expert

The prototype was tested for its feasibility as an exercise game for finger extension. The therapist was told about the purpose and the theme of the game was later asked to play the game. The feedback collected was on the game control. It was commented that the patients may experience difficulty in taping fingers independently. Only the patients who have recovered most of their hand functions would be able to the game. It was suggested that the game's difficulty level could be based on the number of fingers the patient must tap with. So the easiest level will have the patient taping with all the four fingers, a higher level could have the patient tap with two fingers together and the final level could have the patient tap with independent fingers. Thus the patient will have gained independent control of each finger by the end of the final level.

The feedback on the game theme and content was positive. The therapist commented that the task of arranging item in a particular order is also a good exercise for cognition. Too much variety must be avoided as it may be overwhelming to some patients who have mild cognitive impairments.

7 Final Design

Game Name: Raju's Snack Center

Genre: Health & rehabilitation, Family

Purpose and Target audience: The game 'Raju's Snack centre' has been designed for patients in the Brunnstrom stage 3, 4, 5 and 6 of hands. It promotes finger extension through gameplay and can be played by patients who have none to mild cognitive impairment.

Graphics: 2D

Platform: Android Mobile

Game Story:

Raju is an Indian hawker who loves to cook delicious Indian snacks.
His passion for cooking and feeding people is also powered by his great interest in learning about new places and culture of people who come to him as customers. Every time he meets a new customer, he takes the opportunity to have a chat with them and get to know new recipes from their hometown. For now, Raju just has a tiny stall on a tricycle cart but he has big dreams of travelling around the country and collecting as many local recipes as possible. Help Raju make his dreams come true as he works hard everyday cooking, feeding his customers and learning new recipes.

Game Play:

Complete cooking tasks for Raju at different levels by performing the exercise and earn money. Upgrade your stall with the money and unlock new food destinations for a whole new adventure. Make sure you keep your customers happy. They love great food but they love it even more when it's served in time!

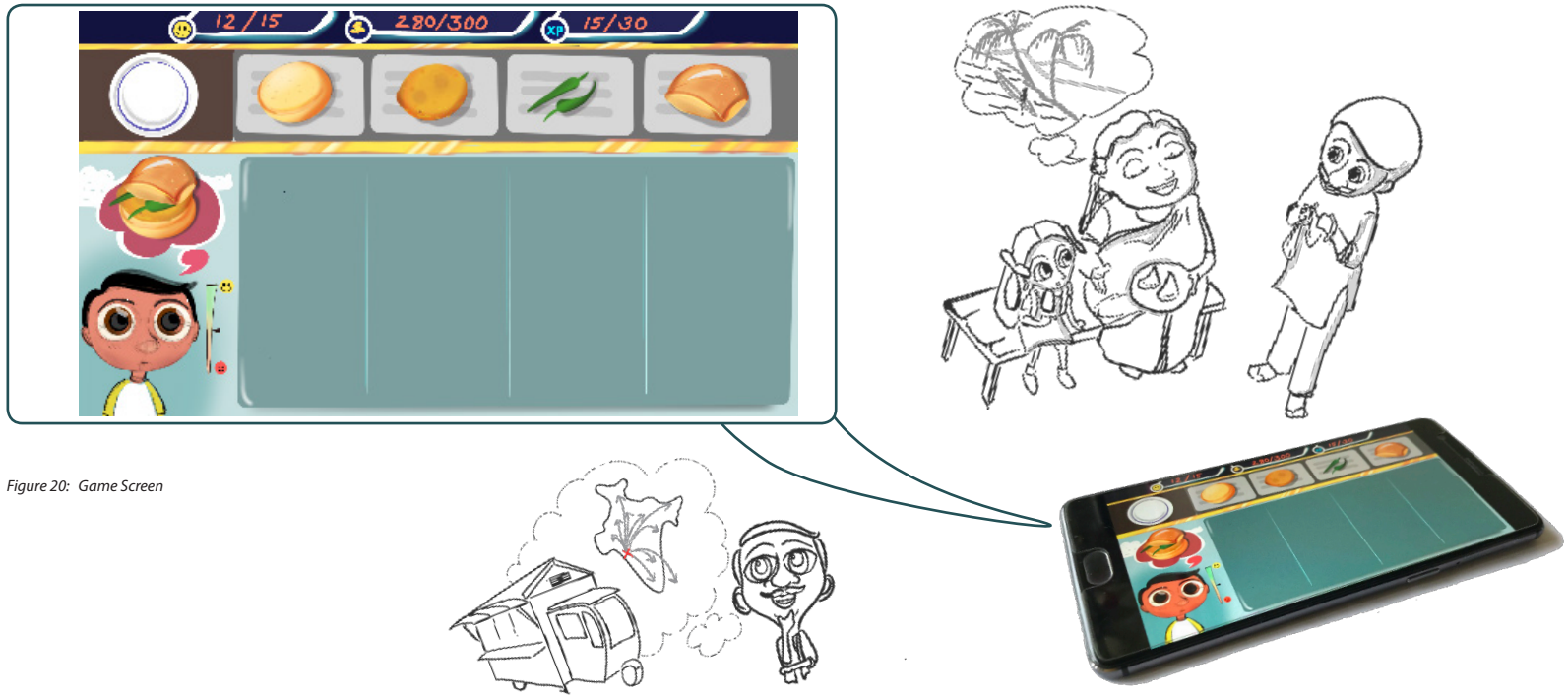


Figure 20: Game Screen

Game Levels:

Different levels for 6 different finger exercises.

1. Tap with all four fingers
2. Tap just with Index finger
3. Tap with last three fingers (Middle, Ring and Little finger)
4. Tap with Index and Ring finger together
5. Tap with Index and Ring finger alternately
6. Tap with individual fingers

First level start with the easiest exercise. Difficult exercises will be added as you progress through different levels and perfect them.

Device position and body posture:

The game allows extension of fingers as the patient interacts with the game through the touch screen device placed at a comfortable height. The patient must rest the fingers on the device as in Figure 21. The arm is at resting position on a table top and the fingers are relaxed. This ensures that no other parts of the arm is in motion except the fingers and thus avoid compensation in movement.

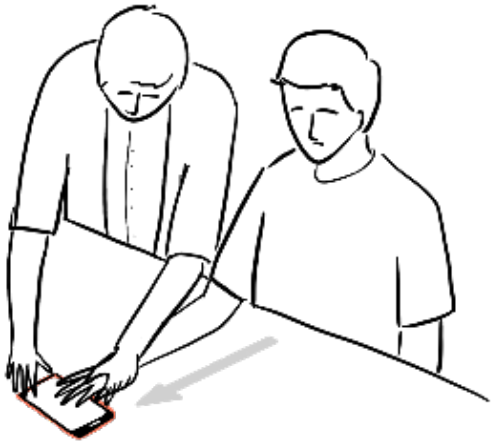


Figure 21: Posture

How will the patient track their progress?

After every game session the patient's average speed will be measured. The patient can increase the speed to beat the previous score next time until he/she reaches the average speed of a normal person. Reaching the normal speed also means that the patient has perfected the level and is recovering. In the game, perfecting a level will unlock new levels for more difficult exercises.

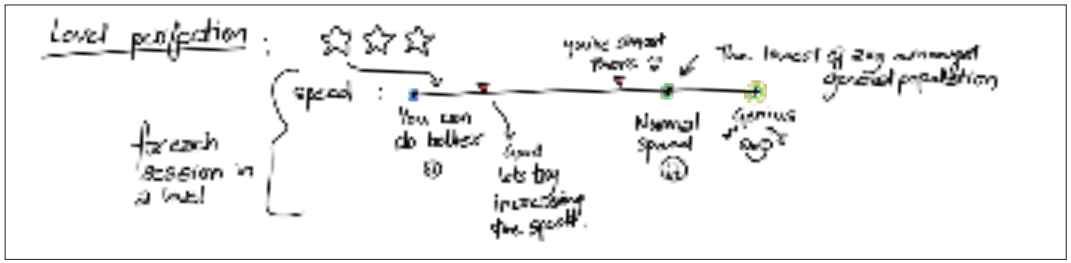


Figure 22: Design idea for level perfection bar

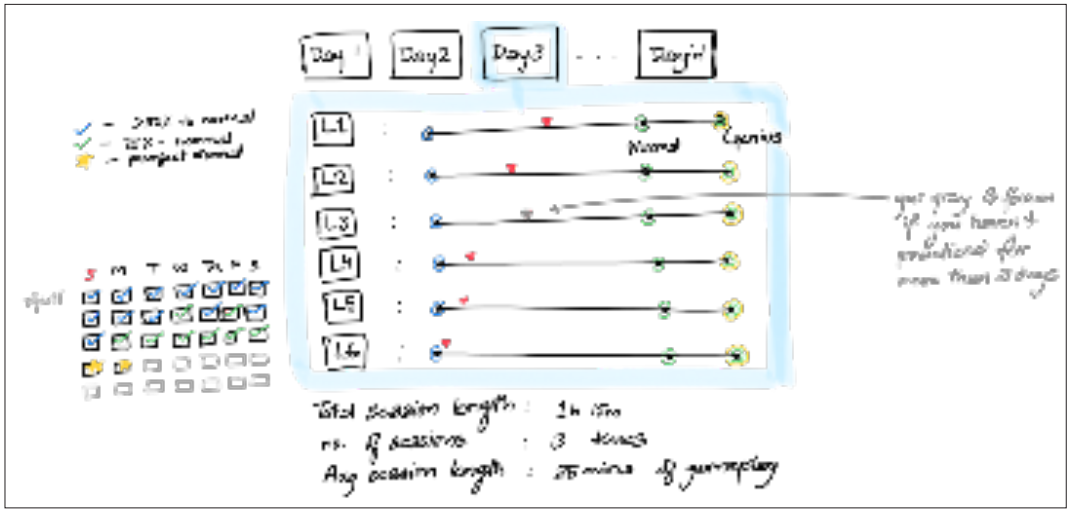


Figure 23: Design idea for tracking daily progress

Other added features:

Tips for improvement will be shown at the end of every session which will be based on the other exercises that the patient can do at home apart from exercising game. These exercises wiwll be related to practicing grips and working on the strength of the hand.

The game emails a report on the patient's progress every week to the therapist. At the completion of all the levels in this game we believe the patient will have gained a fair amount of independent control for each finger of their hand.

7 Evaluation

Expert feedback has been taken for primary touch control of the mobile game. The feedback for the game as an adjunctive therapeutic tool was positive. Suggestions were received to modify the level difficulty based on the type of exercises that would range from ‘movement of all the fingers together’ to ‘individual movement of each finger’. The game was then further modified according to the expert feedback and the final design has been presented.

Testing the game application for its impact on the improvement of fine motor skills of the patients is a challenge as the progress can only be measured effectively over a period of minimum 6-7 months. This will also require extensive ethical clearance for initiating the clinical trial. To access player engagement and motivation, a qualitative study can be done. This will include observation during game play and semi-structured interview after the game session. The player performance will also be measured quantitatively to check for any improvement over repeated play.

8 Conclusion

One of them most distressing losses in a stroke is the use of hands. Although the person may be able to resume walking, they find that they can't coordinate actions in the fingers of the hand because the fingers are particularly requiring more finer control. This can be frustrating to patients as some of them may not be able to carry out activities of daily living despite the overall recovery.

In this project we developed a hand exercise game application for smartphones to provide a daily exercise routine in a low cost and accessible manner. The game can be used by therapists and patients as an adjunctive therapy application during rehabilitation. It will help improve finger dexterity and also helps patients maintain an exercise routine.

The game world and its elements have be contextualised to garner more interest from the players. The primary game mechanics was prototyped and evaluated for its feasibility by an expert therapist. The feedback received were used to develop the game further. This report presents the final design for the exercise game. We hope that the fully developed game would clear the requirements for a therapeautic application and will be available to the patients and therapists for use.

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