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**SERIOUS GAME DESIGN FOR STROKE  
REHABILITATION**

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**SCHOOL OF COMPUTER ENGINEERING**

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**SERIOUS GAME DESIGN FOR STROKE  
REHABILITATION**

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# Summary

Stroke rehabilitation is a challenging process which requires intensive treatments which are time consuming. In order for stroke survivors to relearn basic skills that stroke may have taken away, repetitive exercises need to be performed to improve the functionality of affected limbs. The aim of this research is to introduce actionable steps in designing a motivating stroke rehabilitation game such as an escape room. These actionable steps uses game design concepts of meaningful play, goal-driven and 6-11 emotional framework as well as the psychological concept of familiarity to design game challenges suitable for the targeted demography of elderlies. A video game with Natural User Interface sensors such as Leap Motion and Microsoft Kinect 2 is implemented and evaluated. Participants of the target demography of Singaporean elderlies found the game actions relatable and familiar, similar to their daily living activities. The results indicate potential in creating a replicable motivating and immersive experience for stroke rehabilitation games.

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# Nomenclature

- ADL – Activities of Daily Living
- ERSR - Escape Room for Stroke Rehabilitation
- IADL – Instrumental Activities of Daily Living
- HCD – Human Centered Design
- Rehab – Rehabilitation
- ROM – Range of Motion
- HDB – Housing Development Board

# 1 Introduction

This introductory chapter begins with a background explanation of stroke rehabilitation games. It is followed by the introduction of the motivation of this research. It ends with the organization of this thesis.

## 1.1 Background

Serious game rehabilitation is a process of using video games and design methodology to target and improve therapeutic processes. It has been applied in a variety of situations such as cerebral palsy, stroke and other neurological impairments. With the videogame industry inventing new input hardware devices apart from conventional gamepads, keyboards and mouse, the development of rehabilitation games has reached the lowest barrier of entry over the past decade. Spatial augmentation, virtual reality and motion-based controls play a great part in these enhancements. The inexpensive price of the game devices has provided out of the box support for research and development. This allowed it to be done rapidly with lower cost and lesser time [1][2]. Software tools built for games development, specifically game engines, have grown accessible to the masses as well. Commercial game engines such as Unity3D and Unreal Engine are available gratis; with Unity3D providing support for various input devices making game development for different devices easier. Due to the increase in accessibility and decrease in cost, it is inevitable to see growth in research on games for rehabilitative purposes, such as for stroke rehabilitation [3].

Among all success indicators of stroke rehabilitation, engagement through motivation has been a crucial factor since the design of conventional rehabilitation games. It is often regarded as part of the rehabilitation outcome and high motivation possess many advantages as compared to low motivation. It is more likely for high motivated patients to understand rehabilitation as the most important means of recovery and play an active role in rehabilitation [5]. By playing an active role, patients are significantly more likely to attend their exercise therapy sessions. As patients exhibit this short-term compliance disability and pain levels can be reduced [6].

## 1.2 Motivation for this research

Engagement through motivation in serious games has been pursued and studied by numerous researchers. Serious game design frameworks with different approaches have been created in these researches as well. However, most frameworks created focused on pedagogy. There is a lack in serious game design frameworks targeting stroke rehab. There are certainly stroke rehab targeted serious games researched, with some researchers, like Balaam et al [31][32], incorporating motivation based on game design theories. However, unlike pedagogy, these researches have not created actionable frameworks to replicate their success in designing their serious games.

A methodology created by Yeh et al covers the essential components a good serious game for stroke rehabilitation should possess [9]. Detailed steps were given to elements such as equipment selection and data analysis, however the steps to designing the serious game was not conveyed in his study (Figure 1.1). This lack of design framework is prevalent for other studies [3]. There is therefore a motivation to produce an actionable framework for stroke rehab which can be easily used for creating stroke rehab games with elements for engagement.

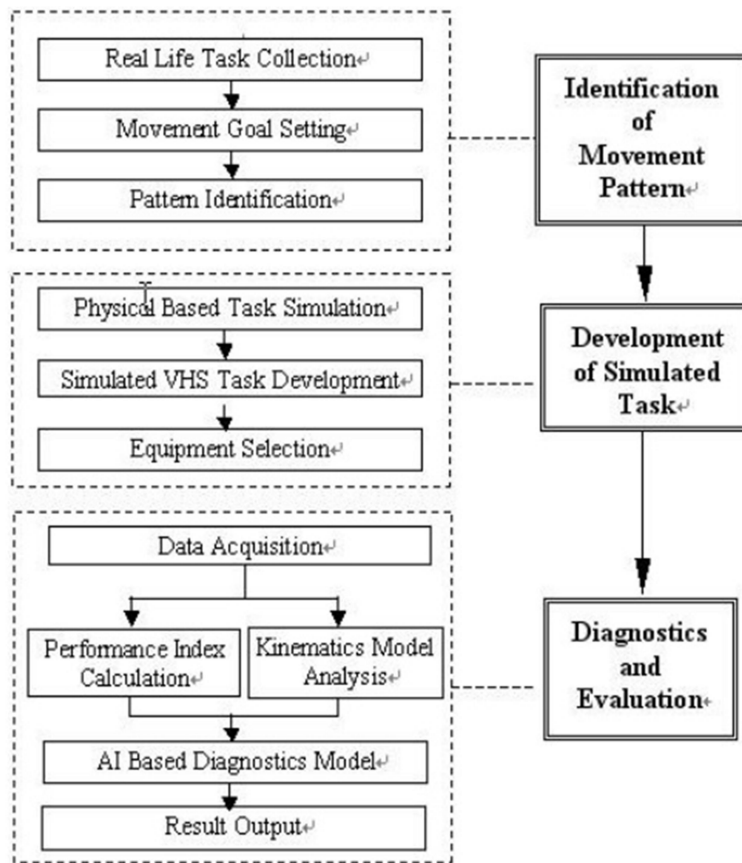


Figure 1.1 Framework of Stroke Rehabilitation Game Design by Yeh et al.

This research analyzes the escape room genre, aiming to use this genre to create steps for an engaging rehabilitation. The genre has the benefits of effectively engage on audiences of different ages, genders and countries. This research repurposed the game genre beyond entertainment and applied it in stroke rehabilitation.

## **1.3 Aims of the Research**

The research aims to fulfill three purposes. Firstly, it aims to create a framework for designing and implementing serious games for stroke rehabilitation. The framework addresses a patient's rehabilitation needs and conveys actionable steps to integrate psychological and game design concepts into rehabilitation.

Secondly, the research aims to design and develop a working demo of a stroke rehab escape room game with natural interface devices such as Microsoft's Kinect and Leap Motion's sensor controller.

Thirdly, the research studies the effects of familiarity, emotional and goal driven design in stroke rehab games.

## **1.4 Significance of the Study**

This research provides a method for occupational therapists to extend the duration a stroke patient's rehabilitation exercise in a non intrusive way using game design and psychology principles. From the elder stroke recoverees' perspective, the stroke rehab games designed can reduce their discomfort of their therapy and increase the chances of their completion.

This research is also benefits researchers who seek to improve the stroke rehab process through games as well. The framework designed in this research will not limit the types of rehabilitation process nor to the tools used in rehab. It is instead additive to ensure a stroke patient is motivated and engaged when playing their rehab games.

## **1.5 Thesis Organization**

Organization of this thesis is as follows: Chapter 2 reviews the current stroke rehabilitation games and escape room games. Chapter 3 breaks down the components for designing an escape room for stroke rehabilitation. It also proposes a design framework. Chapter 4 implements the escape room based on the proposed framework. An implementation framework is proposed at the end. Chapter 5 evaluates the implementation and discusses about the results. Chapter 6 is the conclusions and future works of this project.

## **2 Literature Review**

This chapter aims to introduce some background for the current researches on motivation of serious games and reviews the escape room game genre. The chapter is important to prepare for the analysis of escape room game genre and the design for its serious game counterpart.

### **2.1 Stroke rehabilitation games with motivation**

Motivation and engagement of rehabilitating patients has been an ongoing topic for researchers.

The use of gamification for rehabilitation has shown a degree of success to some researchers. Shah et al implemented a set of stroke rehab games designed with functional tasks and instinctive movements [19]. Scoring mechanism together with small rewards and punishment systems were built into their games to motivate players in performing better. The implementation resulted in general positive feedback by experiment participants; however enjoyment is inversely proportional to the game's difficulty.

Some researchers utilized video game design concepts and applied it to their games. A research by Burke et al incorporated game design theory of meaningful play into rehabilitation [22]. Meaningful play is a concept from Salen et al's book on game design [11]. For play to be meaningful, the actions a player take have to be discernable and integrated, meaning the player has to understand the result of what they are doing and knows that the actions in game make a difference. Burke

et al's implementation created meaningful play using visual and auditory feedback based on player's actions. The feedbacks were intuitively blended into his vibraphone game, which presented a virtual vibraphone with striking colors and produces sounds by hitting its keys. This is in opposition with, Borghese et al, who implemented meaningful play in his framework of minigames too [24]. His implementation of meaningful play presents success and failure to patients by a green tick symbol with pleasant beep for success and red cross with an annoying beep for failure, which may not necessary be fitting to convey meaning. An adaptive design was implemented by Burke et al to maintain a level of challenge based on player's in-game performance as well. However, the adaptive design was deemed too aggressive for some participants.

Lohse et al suggested that applying games into rehab is an interdisciplinary approach involving different components [21]:

- Reward: motivation to play through rewarding experiences
- Difficulty/Challenge: challenge must correspond with level of ability of player
- Feedback: informs about how a skill was performed and its effectiveness
- Choice/Interactivity: constructs active and passive forms of entertainment
- Clear Goals and Mechanics: makes task execution efficient and achievements satisfying
- Socialization: links to increasing amount of time spent playing games

They also took a unique approach to integrate game design, motor learning and neurophysiology changes with rehabilitation science [21].

Flores et al listed a set of gaming design criteria for stroke rehabilitation programs and criteria for elderly entertainment [20]. The list includes providing meaningful tasks, appropriate cognitive challenges and motivational feedback. He proposed that fulfilling a higher number of the criteria can produce a serious game with elderly player higher motivation.

Activities of Daily Living, a healthcare term referring to people's daily self-care activities is used in creating engaging stroke rehabilitation games as well. Hondori et al has stated that by using daily tasks, they believed patients gain confidence in their real daily activities [1]. A similar application of daily activities was found in Sadihov et al's design. One of their games as wiping table, which he stated that exercises performed in the conventional therapy are often based on activities of daily living [25].

## 2.2 Escape Room Games

Escape Room Games originated from point-and-click adventure games, which are video games driven by exploration and puzzle-solving. In these games, players explore and interact with the game surroundings and talk to game characters to achieve game defined goals [26]. Escape Room Games inherit these features of exploration and puzzle-solving. Different from point-and-click adventure, which can take hours to complete, Escape Room Games typically take shorter time to complete, their game surroundings are much smaller, usually in a small enclosed room as opposed to a larger virtual world. Like point-and-click, Escape Room Games have goals that give meaning for completion, though they are simpler and conveyed much straightforward. Their goals normally are to leave confinement by unlocking a prominently located door.

The earliest Escape Room Game is said to be a Japanese online flash-based escape room game named Crimson Room. It was developed by game designer Takagi Toshimitsu in 2004. On the first day of its web release, 200,000 accesses to the game were achieved and eventually this reached accesses of 5 billion by 2008. This instant hit created a world sensation on Escape Room games. The structure of this genre was said to be cemented by Crimson Room. Nowadays it is common to find free Escape Room Games hosted by flash game websites online.

Physical versions of Escape Room video games have also been developed and have grown in popularity in recent years. The earliest

Escape the Room was created in United States, Silicon Valley, by a group of system programmers in 2006. This was followed by Japan in 2008, creating the Real Escape Game by Takao Kato of the Kyoto publishing company, SCRAP Co., and subsequently in Japan, Singapore, Malaysia, Taiwan, Mainland China and Hong Kong. Today there are at least 2,800 permanent Escape Rooms worldwide. Physical, real life, escape room games are similar to video game escape rooms. The goal of these games is to escape from the room by interacting with room objects. Real life rooms are usually bigger, with team-based puzzles required to solve in a limited amount of time.

Aside from entertainment, Escape Room games are beginning to be used in educational serious games. Hou et al has used Escape Room as an education tool to teach students the concept of electromagnetism and application skills [27]. They believed adding game challenges promote student motivation to learn. Their Escape Room game, Escape the Lab, follows a premise of a researcher poisoned by his colleague, resulting in her trapped in her lab. In the game, the player needs to work his way to escape through solving puzzles which incorporates electromagnetism concepts. One puzzle example is letting players use magnetism to pick up a key from an unreachable hole as part of the escape. The game aimed to provide not only a sense of tension but creates tasks to be solved which require learners' observation and exploration skills as well as the ability to simulate and manipulate education related objects. Their research's feedback indicated that simulation manipulation and problem-solving in

escape room games help the exploration and construction of science concepts as well as understanding related knowledge.

## **2.3 Crimson Room**

Crimson Room is the first escape room game to popularize the genre. As one of the first games, Crimson Room contains the basic elements that future escape room games took reference from. Learning about this game equates to understanding the fundamental design of escape room games.

Most escape room games are set in a small, enclosed indoor area. Crimson Room is set in a single room with four walls. The room contains a bed, a cupboard with a stereo system, a plate and four drawers. The room also has a window with curtains and a single door. Escape room games usually used prominent colors for different objects. In Crimson Room, the room is colored red and the door is colored in a prominent blue. The cupboard and curtains are in yellow.

The game begins with the player waking up in the room and realising he is shut in. The player starts in first person view with the door and cupboard visible. This view is powerful as it enables the player to understand both the problem and the solutions. He is stuck in the room, the problem, to open the locked door in front, and the solution is to interact with items to find ways of unlocking, beginning with the cupboard in view. It is effective enough to let players know what to do in the game.

Crimson Room's game camera move towards the object player interacts. At attempting to interact with the cupboard, the view is shifted

and moves to face the cupboard directly. This displays the full view of the cupboard, allowing players to focus fully on this object. Feedback on interactions is direct and immediate. When interacting with the drawers, the drawer is immediately opened and a sound is played. Most objects behave in the same manner, unless it is inaccessible, which the game will inform the player with text. This design of camera is prevalent in most escape room games.

Interaction with objects is the main feature of escape rooms. There are different objects in Crimson Room. These objects are part of the solution to escape through the door. For example, keys are hidden in the CD player and can be used to open locks of the cupboard. By finding all the objects and using the right way, the player will be able to complete the game.

Most Escape Room games follow this basic structure of Crimson Room. The goal of the player is to leave through a prominent exit. The player interacts with different objects in the room in search for materials to help his escape.

# 3 Designing Escape Room for Stroke Rehab

In this chapter, we propose on how to redesign Escape Room for meaningful stroke rehabilitation (rehab). We borrow some of the design concepts suggested by Nicholson to create a meaningful and engaging escape room experience. We also introduce other concepts that fit for stroke rehab. (ERSR) Finally, we propose a design framework for creating meaningful and engaging serious games for stroke using escape room.

## 3.1 Basic Components of ERSR

Firstly we break down ERSR by game components.

Mechanically, ERSR should consist of a game setting, game challenges, game actions and rehab exercises.

Rehab exercises are the physical actions the player performs for rehab. The purpose of rehab exercises is to train patients to regain control of their body functions. These exercises become the game actions performed by players in ERSR to interact with challenges in game.

Game challenges are the puzzles imposed to the player in game. They are what the player solves to progress through the game.

Game setting is the fictional environment where the game is played. Examples are such as a classroom, a park or a house living room.

### **3.1.1 Defining suitable rehab exercises for ERSR**

In order to be effective, efficient and safe for the patients, the rehab exercises must possess the following characteristics:

- An objective to train a desired movement purposefully
- Movement is repetitive, elaborate and task specific
- Movements must be within the capability of the patients

Our objective is to design a game with above characteristics while providing an engaging and meaningful gaming experience to patients.

The research focusses on upper limb rehab as upper limb impairment is the most common, with 85% of stroke survivors experiencing some degree of paresis and 50% experiencing in the chronic phase [60][61][62]. This is suitable as escape room games focus on upper limb actions as well.

The Fugl-Meyer Assessment (FMA) is chosen to collect an exhaustive list of actions the human upper limbs can perform and commonly measured for stroke recovery. The assessment is one of the widely recognized and clinically relevant measures of body function impairment after stroke using the Brunnstrom Approach [54]. Designed to assess five domains in patients with post-stroke hemiplegia, FMA consists of motor functioning, balance, sensation, joint range and joint pain. Extracting from the list, 5 sets of upper limb movements are identified. This includes:

- 6 shoulder movements: abduction, adduction, internal rotation, external rotation, flexion, extension.

- 2 elbow movements: flexion, extension
- 2 forearm movements: pronation, supination
- 5 wrist movements: flexion, extension, circumduction
- 7 hand/finger movements: mass flexion, mass extension, hook grasp, lateral grasp, cylindrical grasp, index-thumb grasp, spherical grasp

Rehab exercises defined for ERSR must be within the above movements and follow the aforementioned rehab exercise characteristics.

### **3.1.2 Creating challenges**

#### **3.1.2.1 Goal driven**

Goals of a stroke patient are important in creating an effective stroke rehab. A study by Resnick et al was conducted to understand the relationship between elderly's motivation and improvement of function [16]. They explored what motivates elderly to perform functional activities and in their results goal is one of the five major themes categorized, together with personality, beliefs, fear and physical factors. Patients in the study described identifying goals as helping them motivated in performing functional activities and decreased the influence of negative physical sensations when performing therapy.

The importance of goals is mentioned in games as well. According to Nicholson, one of the three ways of creating meaningful escape rooms is to have challenges with a direct impact on the player [63]. In other words, a challenge needs to have a positive effect to completing the game. This concept can be traced from Salen et al's book on game design in the form of player goals, who states that every game has long term and short term goals [11]. A long term goal is the win condition, whereas short term goals are tiny moments of play that move a player through a game to fulfill the long term goal.

In ERSR, challenges must perform as short term goals for moving through the game as well as moving through the patient's rehab process. The long term goal of game completion should be connected with the goal of fulfilling the patient's personal goals.

### 3.1.2.2 Familiarity

A common issue of modern technology is that technologies such as games can be difficult for elderlies to use. This is often because they are not designed around the understanding of elderlies. What most users of technologies assumed to be natural affordance may not accurately interpreted by elderlies [13].

The concept of affordance is brought out by Norman in human-centered design approach [43]. Affordances determine what actions an object can do. An object designed with good affordance is easiest to learn its functions as its controls, actions and intended results are mapped with good understanding by targeted users. Thus it is preferred to design in mind of affordance from the perspective of elderlies and communicated with just enough assistance for elderlies to perform without much support.

A method to design with natural affordance is to use objects familiar to elderlies. Familiarity, meaning to possess prior knowledge, is proposed as a holistic approach to introduce technology to older people by making it easily understood and relatable [13]. In human-computer interaction, three dimensions of familiarity elements should be satisfied [15]:

- **Symbolic Familiarity** is achieved by infusing objects, activities or processes occurred in user's daily living into design.

- **Cultural Familiarity** is achieved by incorporating concepts, artifacts, patterns, traditions, or rituals commonly user's culture into the design of the system.
- **Actionable Familiarity** will be achieved when elements interact and behave as their counterparts in real life.

While symbolic and cultural familiarity is dependent on individuals, escape room games widely incorporate actionable familiarity in their design. In Crimson Room, it is set in a room with items commonly found in a bedroom. This includes a bed, window, cupboard, bed, stereo and door. At interacting with the items in game, they behave exactly like their counterparts in real life, a cupboard drawer can be drawn out and pushed back in, and CDs can be inserted and ejected from stereo.

By creating a context suitable for elderlies to evoke symbolic and cultural familiarity, challenges in ERSR will be able to achieve all three elements of familiarity.

### **3.1.3 Choosing a coherent game setting**

In order to create a coherent experience familiar to elderlies, the setting must be within the same context as the game challenges. This means there should be a reason why challenges are being performed in the game; there must be a reason for elderlies to perform the challenges in the provided setting. Tsoupikova et al created a game in the context of a tea party [55]. The actions performed by their users in game involves catching cookies scurrying away on the table, filling teacups with teapot, pinching sugar cubes into teacup, etc. The setting of a tea party makes sense for players to perform these actions as it gave reason behind them.

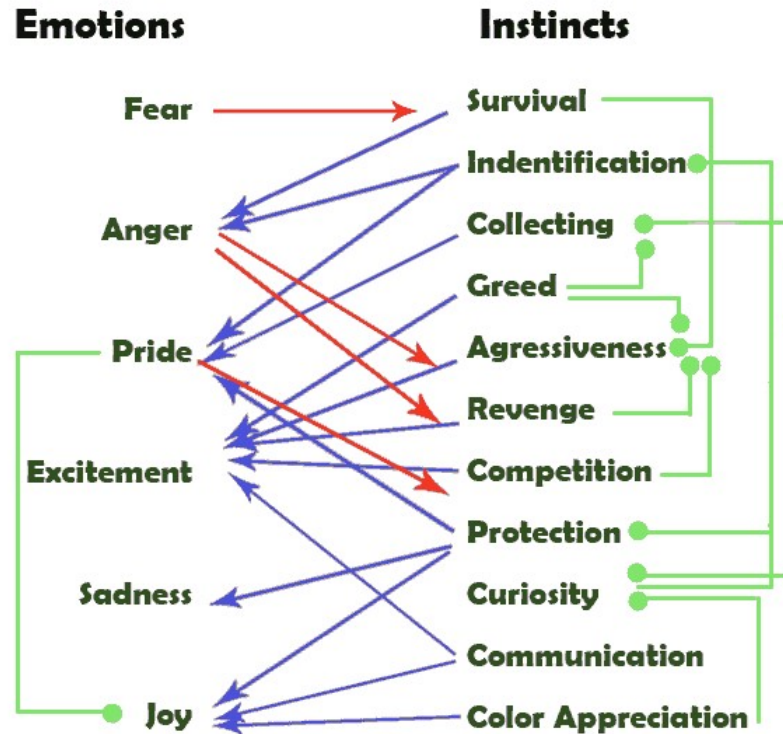
The escape room genre is flexible in using different settings and locations to create challenging puzzles coherent to the settings. This can be seen in games like Escape the Phone Booth, the player tries to escape from a telephone booth [44]. In this game, the main puzzle interactions uses the paid telephone by inserting coins into machine, picking up the handset and dialing numbers. This flexibility allows for designs following a particular context and following a themed set of activities suitable for ERSR.

## **3.2 Evoking emotions through design**

Emotions of stroke patients play a large role in rehab. Fear is one of the emotions that can cause patient's resistance to rehab. In Resnick's research, the fear of falling caused rehab participants to avoid leaving the wheelchair in fear of falling again. Frustration is often evoked due to the pain induced during the rehab process.

Although it is possible to evoke fear for engagement and it is often used in escape rooms, our aim is to create a game which elderly patients feel safe and is willing to participate in rehab repetitively. For this reason, we need a method to address patient emotions in our game design.

A 6-11 emotional framework was theorized by Dillon to structure basic emotions and instincts evoked by humans when they play. His concept states emotions cannot be controlled but can be led to by human instincts. Instincts, however, can be triggered by particular events in the environment automatically. This ability to indirectly affect the player's instincts through game design can trigger emotions interrelated to the instincts (Figure 3.1). Our aim in applying the 6-11 framework is to design a game that evokes the emotions suitable for rehab and prevent unsuitable ones from being evoked.



Roberto Dillon. A few main relationships between basic emotions and instincts

Figure 3.1 Main relationship between basic emotions and instincts.

Dillon proposed this set of aesthetics with six emotions, eleven instincts and interactions between them. He stated six types of emotions as:

- Fear: Most common emotions in games nowadays. Fear can be easily invoked with the introduction of new technologies, realistic situations and environments.

- Anger: Strong emotion used to motivate players to retry or used to encourage advancing into story and stop wrong doings of villains.

- Joy or Happiness: Arguably the lead emotion for creating a fun experience in gaming. This is usually caused by a player's success in a

task and rewarded by something significant like upgrades or storyline progress for example.

- Pride: An important motivation of players and rewards a pleasurable emotion for their triumphs. It is vital to push players to be better and progress through game challenges.

- Sadness: Contrary to the emotion which deemed opposite of fun, it is seen by many game designers as a source to reach artistic heights and to go upon mature and complex themes.

- Excitement: It is considered that games should achieve this natural excitement. It should be evoked together with other emotions or instincts.

Eleven instincts he stated are:

- Survival: A basic and primitive human instinct. It is evoked when life is threatened. Based on the situation, our flight or fight instinct will decide the best solution. The most used instinct in modern video games.

- Self-identification: The tendency to adore people of success or fictitious characters. We naturally would project ourselves being like these models.

- Collecting: Powerful instinct linked to a spread of other emotions. This is used frequently in games.

- Greed: When simple collection is not enough, people would amass more than one actually needs for sense of satisfaction. No matter rare items in games or the accumulation of resources, instinct of greed triggers frequently in many games.

- Protection or care or nurture: This is argued to be the most positive instinct as it pushes parental love towards children and to feel an urge to care and help people or animal in need.

- Aggressiveness: An opposite of Protection. The instinct is triggered often by anger or greed. This is used in many games.

- Revenge: A strong instinct capable to be a motivation. It is widely seen to advancement in storyline or justification to defeat villains.

- Competition: A deep link with social aspects. It is an important instinct used in gaming. For example is the use of leaderboards that forms a great appeal to games.

- Communication: Expression of thoughts or ideas. A great aspect in human evolution and also has a great effect in games as well.

- Curiosity: Major discoveries and advancements are caused by this instinct as it pushes our path towards unknown territories.

- Color appreciation: We humans are attracted to vibrant colors; we naturally seek detail and colorful graphics. It is a great trend in games now.

The school of thought behind this 6-11 Emotional Framework is that in order to create a fun and meaningful experience, games must be designed around these instincts and emotions, to build a network leading to Joy or Excitement. This network relates different emotions with different instincts, where instincts are triggered by gameplay and emotions are evoked naturally in the process.

### 3.3 ERSR Design Framework

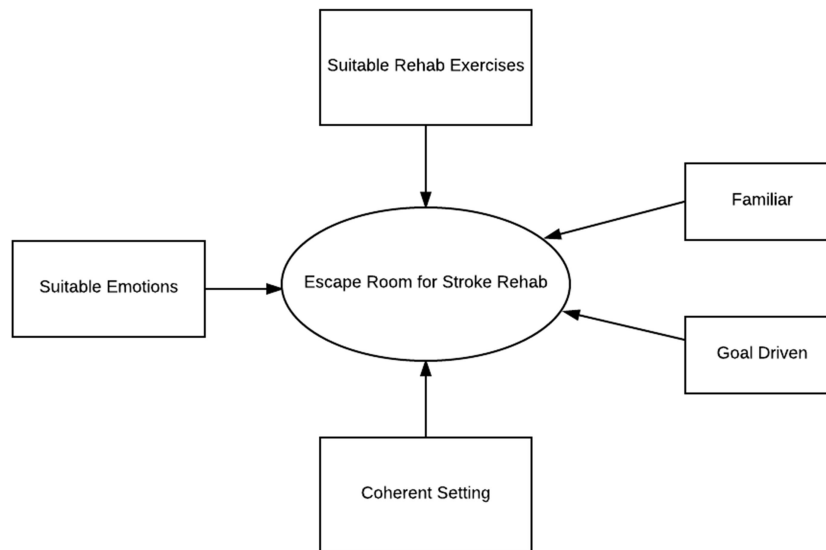


Figure 3.2 Escape Room for Stroke Rehabilitation Design Framework

The ERSR design framework summarizes our design decisions for ERSR (Figure 3.2). The creation of an escape room suitable for stroke rehab depends on the four elements around it. Suitable rehab exercises are to be selected for the rehab patient. Based on the exercises, game challenges which are goal driven and familiar needs to be created with a game setting coherent to the challenges. The challenges and settings should prevent negative emotions such as fear from being evoked while patient plays and positive emotions like joy should be evoked. The design framework is separated from the implementation framework as the implementation decisions may change depending on context while the fundamental design framework will remain the same.

## **4 Implementation of ERSR**

Using the design framework we established, we implemented a prototype of Escape Room Rehab Game. A list of rehab actions is to be selected to implement the Escape Room Stroke Rehab Game (ERSR). In reality, this step should be selected by physiotherapists. For the purpose of this research, twelve upper-limb motor activities were selected. A list of instrumental activities of daily living (IADL) is then selected. Both lists are matched based on the similarity of the motions. The stroke patient's demographic is then considered in planning the game's setting and possible game actions. The game actions are matched with the ADLs and rehab actions.

### **4.1 Demographic of users**

Our implementation defines a stricter base of target audience. Based on the "Trends in Stroke in Singapore" report from Ministry of Health Singapore, from 2009 to 2013, the total number of stroke patients is 6558, with 57% of them to be male and 43% female. This can be understood that both genders are almost equally likely to suffer from stroke (Figure 4.1).

Gender	Race	Ischaemic	Haemorrhagic		Unknown	Total
			Subarachnoid	Parenchymal		
Male	Chinese	2284	42	508	13	2847
	Malay	488	13	86	0	587
	Indian	251	2	32	0	285
	Other	62	3	12	0	77
	Subtotal	3085	698		13	3796
Gender	Race	Ischaemic	Haemorrhagic		Unknown	Total
Female	Chinese	1645	91	346	10	2092
	Malay	343	22	68	0	433
	Indian	151	3	19	4	177
	Other	47	4	9	0	60
	Subtotal	2186	562		14	2762
Grand Total						6558

Figure 4.1 Number of Stroke (First-Ever and Recurrent) Cases among Singapore Residents admitted to Public Hospitals, 2013

The crude incidence rates (a measure of the number of new cases in a given time span) of stroke patients among different age groups are tabulated. The rate grows exponentially by age, most significantly from age of 45 onwards. In other words, most stroke patients are of age 45 and above.

Our implementation aims to target the common Singapore's stroke sufferers. Taking from the data above, we select a range of 50 to 65 years old elderly Singaporeans of both genders to be our users for this implementation.

## 4.2 Deciding rehab exercises

As mentioned in our design, rehab exercises for ERSR must be within the five sets of upper limb movements and follow the characteristics in 3.2. We looked into different upper limb rehab protocols to find exercises with elaborate and repetitive characteristics.

In the shoulder rehabilitation protocol by Princeton University, rehab exercises are within the components of strength and flexibility. Strength exercises focus on strengthening different upper limb muscles either with dumbbell, tubing or body weight. Stretching exercises have lower repetitions and consists of

- Range of motion (ROM), where desired degrees of range of motion of movement pattern is performed pain free. It may be assisted with items like stick or towel or performed unassisted.
- Static stretching, which involves holding to a certain position pain free and for a period usually 20-30 seconds.
- Dynamic stretching, performing repeating movement of multiple joints.

Elbow rehabilitation based on Morrey et al's The Elbow and its Disorders defined four types of ROM, active assisted, active, passive and resisted [64]. Simmons et al recommend four types of common exercise for people with hand and wrist problems [65]. Similar to shoulder rehabilitation protocol, it consists of ROM exercises, stretching exercises, strengthening exercises and an additional resisted isometrics, which is

the strengthening the resistance of joints and muscles against external force.

Understanding from the above protocols, upper limb movements can be trained either in isolation or combined and within ROM. Exercises can have different

- Joint angle, speed, weight, resistance
- Purpose: stretching or strengthening
- Type: active, passive or assistive
- Performing postures

Our implementation will use upper limb movements trained isolated within active ROM, focusing on flexibility and with fixed number of repetitions.

### **4.3 Selecting hardware and identifying constraints**

As our implementation focus on exercises within active ROM, hardware is chosen to receive these actions as game inputs. The hardware is required to detect all of the upper limb movements identified in Chapter 3. Two different devices are chosen for the implementation. Both devices are Natural User Interface (NUI) hardware capable of providing motion controls. Spatial gestures can be customized and detected by both devices.

The Kinect V2 is chosen as it is able to detect shoulder and elbow movements with high accuracy. After our review of Kinect's technical capabilities, the device is not sensitive enough to detect precise wrist and hand movements. The Leap Motion is chosen as an additional device to provide additional support to these movements. The combination of these two devices allows for the coverage of all 5 sets of upper limb movements identified.

## **4.4 Decisions of challenges**

### **4.4.1 Using IADL for goal driven challenges**

Based on our design, challenges in ERSR needs to be goal driven and familiar for elderlies.

In 3.3.1, we mentioned that games have long term and short term goals. This is equivalent to rehab in the form of specific and general goals. In Resnick's research, the goals can be specific, like regaining the ability to walk a short distance or being able to stand up from a chair, or general goals of regaining independence [16]. Maintaining independence is one of the common goals identified by stroke patients.

A widely recognized method to measure reaching the general goal of independence is by measuring the ability to perform instrumental activities of daily living (IADLs). IADL is a set of activities classified in healthcare that is important for living in a community independently. Basic IADL includes house maintenance and cleaning, money management, locomotion, food preparation, shopping for essential items, taking medicine and ability to use communication tools.

ERSR is advantageous to design around the general goal of fulfilling a set of IADLs with specific goals as completing specific IADLs. The escape room genre is recognizable to set in a daily living setting with intractable daily living objects. Crimson Room is set in a bedroom with daily objects like a bed, windows, curtains, cupboards and stereo. Escape the Phone Booth is set in a phone booth with a coin paid phone, phone directory and coins. Room Bath is set in a bathroom with a bath tub, toilet and washing area.

The use of IADLs is used in other serious game designs as well. Mentioned in Chapter 2, Hondori et al used tasks of daily life in their game design. They noticed that patients gained confidence in performing real activities by practicing similar virtual activities during therapy. [1]. Sadihov et al designed one of their games as wiping table, as exercises performed in the conventional therapy are often based on IADL [25].

#### **4.4.2 Addressing familiarity with IADL challenges**

The challenges using IADLs must fulfill the three familiarity characteristics to be effective in invoking familiarity with elderlies. As our targeted demographic are elderly Singaporeans, we must select a set of IADLs common to the daily living for this demographic.

In 2011, a total of 10,000 households with at least one household member aged 55 or older were surveyed in the National Survey of National Citizens [36]. In an approximately 65% response rate, 5,000 senior citizens were successfully interviewed. The National Survey used the Lawton IADL performance indicator in their interview with elderlies, where 91-99% of the respondents were able to perform the activities independently. Taking from the survey and results, Lawton IADLs is important for elderly Singaporean's daily living and are familiar enough for able-bodied elderlies to respond to the survey properly (Appendix 1).

### **4.4.3 Complexity of challenges**

In designing meaningful challenges, Nicholson states that a balance is required for physical effort and mental inspiration to solve. This means that the puzzle element in challenges must not be so complex that multiple physical cause player frustration. Another design aspect by Nicholson is having clear solution for puzzles. Having a clear goal is also supported by Lohse et al, who stated that goals can lead to a higher chance of acceptance [21].

These design aspects and the requirements of rehab drove our decision to remove puzzle elements from this implementation. In our designed rehab exercise characteristics, exercises need to be trained purposefully and with repetition. In most cases, the amount of actions performed by patients in each session is fixed. Increasing the amount of repetition because of puzzle complexity may lead to patient frustration and this is not acceptable. As such, challenges are designed to be completed by repeating a designated upper limb movement for specific IADLs with fixed repetitions. Movements are performed without any time limit and there is no failure of challenges.

## 4.5 Selecting the game setting

In 4.4, we have established that the IADLs selected are focused within a household. In order to create a coherent game, the setting needs to be the same as well. As such, we use the setting of the common living room of elderlies in Singapore. Based on the National Survey of National Citizens, 85.5% of elderly of age 55 and above stays in a public housing unit managed by the Housing Development Board (HDB flat) [36]. Therefore, to cover the larger group of our target users, we set the game in a HDB flat. The implementation is referenced from the common 3-room HDB flat in Singapore established in 1970s. The aim was to recreate the correct layout of living rooms of that time. As with older flats in Singapore, colors of the house are monotonous, with white square tiles and white walls and ceiling. Fans are either wall mounted or standing and lighting is created by ceiling lights. The windows and main door are installed with checkered window grills, a design prevalent in that particular time of Singapore (Figure 4.2).



Figure 4.2 A 3-room flat at Bendemeer Road located in an estate established in 1972.

Our implementation used a similar layout and size of a real-life 3 room flat. The walls and floor tiles are created to match designs of these flats with essential installations like gates, doors, windows and window grills designed to look as closely real-life as possible (Figure 4.3). Furniture and household items are created for placing items for different challenges.



Figure 4.3 Implementation of ERSR game setting

As the game setting is a natural location for elderlies to perform IADLs, the game challenges can be populated based on the logical positions of intractable items. For example, a phone can be on a coffee table, whereas food cleaning can be done at the kitchen sink.

## 4.6 Planning the puzzle path

Referencing from Wiemker et al's design of escape rooms, we implemented an open path puzzle path design. In an open path, challenges can be worked on in any order and the final challenge will be worked on after all other puzzles are complete.

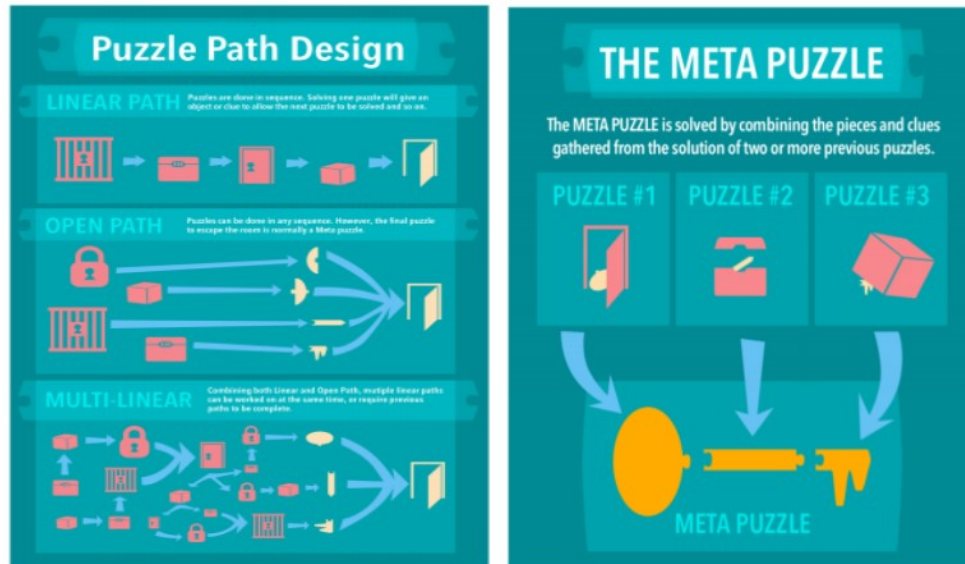


Figure 4.4 Wiemker et al's explanation on Puzzle Path Design and Meta Puzzle

As any order of completion is viable, the sequences of challenges are randomized and players attempt each challenge one after another. This guided experience is beneficial for rehab, as it allows patients to focus on each rehab exercise one at a time with fixed repetition.

The concept of an open path is suitable for designing the escape room with a meta puzzle, where a final challenge can be solved only by combining the pieces gathered from solving all previous challenges. The relationship between the different challenges with the final challenge helps to increase the relationship between the short term and long term goals in ERSR.

## 4.7 Addressing player emotions


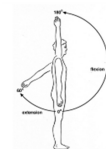
Our implementation references from the 6-11 emotion framework by Dillon to address the emotions players might evoke when playing ERSR (Figure 3.1).

ERSR focuses on the basic instincts of collecting and curiosity. Collection is created through the implementation of the meta puzzle, parts of the solution for the final challenge is collected throughout the game. Our implementation plans to create multiple challenges for the each upper limb movements. The possibility of interacting with a different set of challenges on a randomized path makes each game session a new experience. This can evoke a curiosity instinct in the player. Curiosity and collecting are complementing instincts that often evoke together. We make use of the human instinct of attracting to vibrant colors and implemented using vibrant colors for game items to evoke the instinct of color appreciation as well.

In Dillon's concept, instincts can lead to interrelated emotions. Our implementation aims to prevent negative emotions such as fear, anger, and sadness to occur while evoking positive emotions such as joy and excitement. Based on the main relationship diagram between emotions and instincts, the collecting instinct evokes pride. This is a pleasurable emotion as it pushes players to progress and be better. Pride and color appreciation can indirectly evoke the feeling of joy. Dillon has stated that games need to have either excitement or joy to create a fun experience. Our identified instincts are less likely to evoke the negative emotions stated above.

## 4.8 Implementing ERSR functional prototype

The functional prototype of ERSR is created for a proof of concept. Six IADLs are selected and developed into challenges in this implementation. As most IADLs are complex actions requiring combined upper limb movements, to match with our upper limb isolated movements, we selected suitable IADLs for our game and break down each IADL into their basic upper limb movements. This is followed by choosing a single upper limb movement to represent each of the selected IADLs in consideration of actionable familiarity (Table 1). The movements can be performed by either upper limb. From the table, it is shown that multiple challenges have the same upper limb motion selected. This design choice is made to allow patients experience different game challenges each time even when they are required to perform the same upper limb motions in rehab.

Game challenge	IADL category	All upper limb motions required	Upper limb motion selected	Image of selected motion
Clearing the table	Housekeeping	Shoulder flexion, shoulder extension, shoulder abduction, shoulder adduction, elbow flexion, elbow extension, finger mass extension	Shoulder adduction	 A diagram of a human torso showing the right arm moving towards the midline of the body. A red arrow points from the shoulder towards the center, labeled 'ADDUCTION'.
Tidying book shelf	Housekeeping	Cylindrical grasp, shoulder flexion, shoulder extension, shoulder abduction, shoulder adduction, elbow	Shoulder flexion	 A diagram of a human torso showing the right arm moving upwards and forwards. A red arrow points from the shoulder towards the top of the frame, labeled 'FLEXION'.

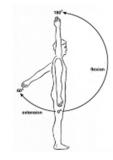


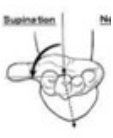
		flexion, elbow extension, forearm pronation, forearm supination		
Hanging laundry	Laundry	Forearm pronation, forearm supination, elbow flexion, elbow extension, cylindrical grasp, shoulder abduction, shoulder adduction, shoulder flexion, shoulder extension	Shoulder flexion	
Washing dishes	Food preparation	Shoulder internal rotation, elbow flexion, elbow extension, index-thumb grasp, shoulder abduction, shoulder adduction	Elbow flexion	
Switching television channels	-	Index-thumb grasp, forearm pronation, forearm supination, elbow flexion, elbow extension	Elbow flexion	
Opening lock	Transportation	Index-thumb grasp, forearm pronation, forearm supination, elbow flexion, elbow extension	Forearm supination	

Table 1: Game challenges with corresponding IADL and upper limb action

A meta puzzle is created with the final puzzle a lock opening challenge. The keys used to open the lock are collected from the previous challenges in game.

Before the start of each game session, the number of rehab exercise repetition can be specified for each challenge. Completion of each challenge forwards the player to the next challenge until the final challenge.

### 4.8.1 Heads Up Display (HUD) Interface

A progress bar is displayed at each challenge to indicate the number of actions needed to perform to complete the challenge. The bar is empty at the start of each challenge and fills up as player progresses in the challenge (Figure 4.5).

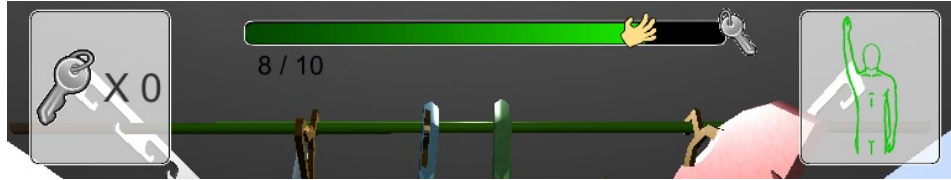


Figure 4.5 Heads Up Display Interface

A box at the top right of the screen displays the upper limb action the player needs to perform. The action changes for different challenges. The box at the top left of the screen shows the overall progress of the player in ERSR. Initially the box indicates the player does not carry any keys. Keys are accumulated when player progresses and the number of keys are indicated in this box (Figure 4.6).



Figure 4.6 Obtaining key

## 4.8.2 Clearing the table

The clearing the table challenge is categorized under housekeeping in Lawton's IADLs. The challenge requires player to perform the shoulder adduction action (Table 1).

The table is littered with different objects and needs to be cleared. As the player performs the shoulder adduction action, objects gets cleared. A key is found hidden within the pile of objects when all objects are cleared away (Figure 4.7)

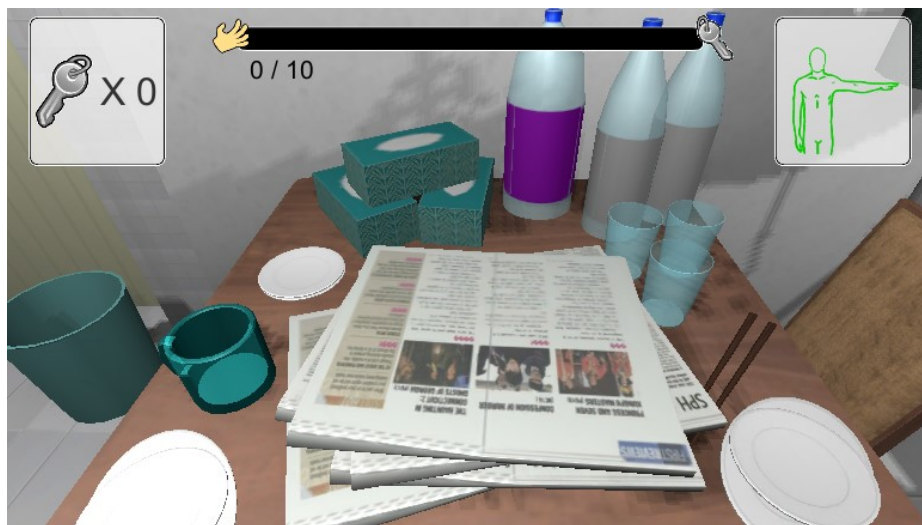


Figure 4.7 Clearing the table in ERSR

### 4.8.3 Tidying bookshelf

The tidying book shelf challenge is categorized under housekeeping in Lawton's IADLs. The challenge requires player to perform the shoulder flexion action (Table 1).

Books on the shelf are unorganized and messy. As the player performs the shoulder flexion action, the books are taken up to the upper row and placed upright. A key is found hidden in the books when all books are transferred to the upper row (Figure 4.8).



Figure 4.8 Tidying book shelf in ERSR

#### 4.8.4 Hanging laundry

The hanging laundry challenge is categorized under laundry in Lawton's IADLs. Similar to tidying book shelf, the challenge requires player to perform the shoulder flexion action (Table 1).

Laundry is washed and needs to be hung in the kitchen. Each piece of clothes is being raised and hung on the hanging pole by performing the shoulder flexion action. A key is found hidden in the bottom of the laundry basket when all clothes are hung (Figure 4.9).

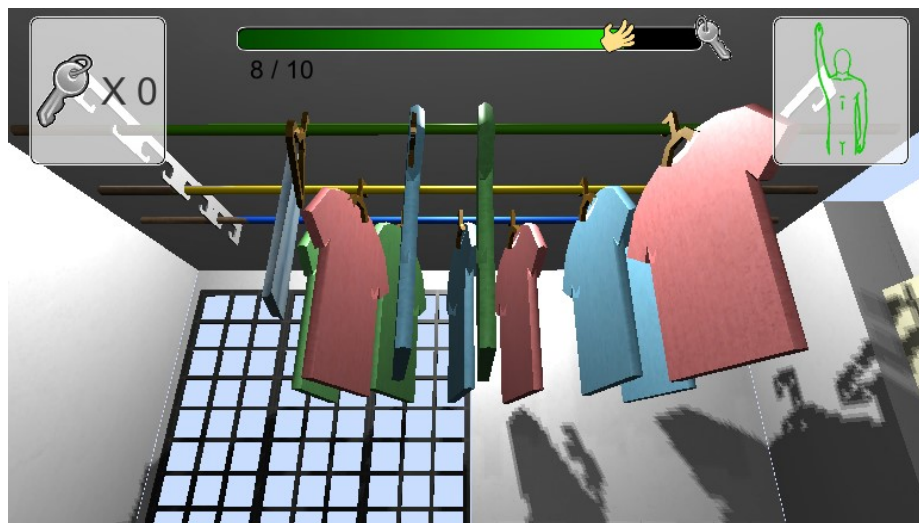


Figure 4.9 Hanging laundry in ERSR

#### 4.8.5 Washing dishes

The washing dishes challenge is categorized under food preparation in Lawton's IADLs. The challenge requires the player to perform the elbow flexion action (Table 1).

A ton of greased dishes are piled in the kitchen sink. As the player performs the elbow flexion action, dishes are dipped into the water, rinsed and placed in the drying rack. On washing all the dishes, a key is found at the bottom of the sink (Figure 4.10).



Figure 4.10 Washing dishes in ERSR

#### 4.8.6 Switching television channels

Switching television channels does not belong in any Lawton's IADLs. It is however a daily activity and is included for more engagement. It requires the player to perform the elbow flexion actions, like washing dishes (Table 1).

The television screen displays an image of a local channel program. The player performs the elbow flexion action to raise the remote and change the channel. After changing the channels for a set number of times, a key appears (Figure 4.11).



Figure 4.11 Switching television channels in ERSR

#### 4.8.7 Opening lock of house gate

The opening lock of house gate is the final challenge of ERSR. It is accessed after completing all previous challenges. The challenge requires players to perform the forearm supination actions (Table 1).

The lock on the gate is the only thing that prevents the player from leaving the house. The player uses all the keys collected in previous challenges and tries to open the lock by performing the forearm supination action. When all the keys are used up, the lock opens and the player exits the house, winning the game (Figure 4.12).



Figure 4.12 Opening lock of house gate in ERSR.

## 4.9 ERSR Implementation Framework

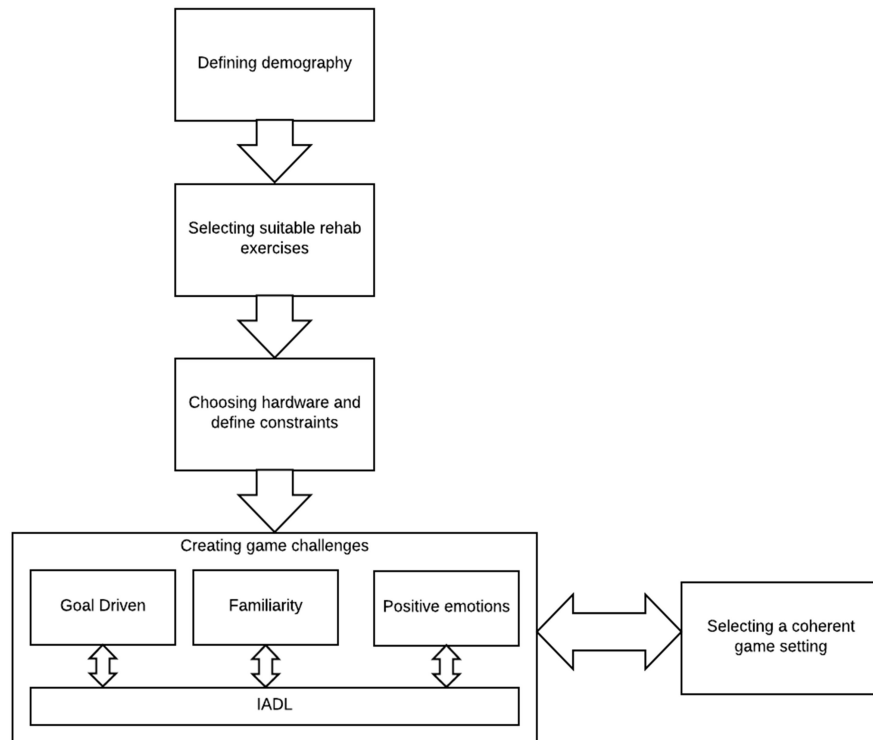


Figure 4.13 Escape Room for Stroke Rehabilitation Implementation Framework

The implementation framework is based on the design framework in Chapter 3. Referencing from Yeh et al, stroke rehab game design is separated by three general steps. Firstly in Identification of Movement Pattern, the therapist sets the rehab plan and personal goals with elderly patient. Secondly, the game is developed in Development of Simulated Task. Finally, rehab is analyzed through Diagnostics and Evaluation. Our implementation framework focus on executable design plans for serious games, replacing the Development of Simulated Task (Figure 4.13).

Summarizing the chapter, the framework begins with understanding the demography of the elderly patient. This includes understanding what the elderly performs daily, their preferences and habits. Suitable rehab exercises are selected for the patient, with hardware chosen based on the content of the exercises and elderly's capabilities. Challenges are created based on the selected rehab exercises and hardware, while ensuring that they are goal driven, familiar and possess positive emotions for the demography of the elderly. For this implementation, IADLs are used to satisfy these characteristics. Lastly, the game setting must be coherent with the challenges to make a coherent experience throughout the game.

# **5 Evaluation of Implementation**

## **5.1 Method of evaluation**

The purpose of the evaluation is to understand the effectiveness of implemented game in terms of familiarity and motivation for the targeted demographic.

The implemented game was evaluated with five able-bodied elderlies aged between 55 to 60. The participants played through the game once and were interviewed regarding their perception of familiarity and motivation in relationship with the game. Evaluation sessions were scheduled for 45 minutes for each elderly. Qualitative results of the evaluation are presented below.

## **5.2 Evaluation Results**

### **5.2.1 Familiarity of the setting**

In the five sessions, our participants reported that they are able to identify the game setting to be a living room in a HDB flat.

“It (the setting) looks almost the same as my home”

“Looks like a 3-room flat, same as my home, mine is also a 3 room flat.”

When asked about the similarity and differences compared to their home, most replied with minimal differences. One participant reported the difference in design of the windows.

“We have television, steel gate; it’s just that the steel gate looks different.”

“The windows are different, “pointing at the kitchen’s window  
“mine is bigger, mine is the older one, and this could be the newer designs.” “Mine spans across the wall”

### **5.2.2 Familiarity of the challenges**

The participants reported that the daily activities implemented in the challenges have close resemblance to the activities they need to perform daily. This is most apparent for housekeeping and laundry.

“Because it is home, so it needs to be clean”

“We wash dishes, cook on our own.”

“We do hang our clothes on hanging poles, but we hang it outside”

“We’ll hang them on a metal pole and push it to the outside”

The action of tidying up bookshelves is performed mostly by elderlies with family visiting them weekly.

“My grandson would come and play, I tidy up, clean dusts, sometimes cooks”

Most participants suggested including more daily objects and actions they performed daily.

“I think there can be a fridge, to store some meat, some vegetables.”

“There can be a stove for cooking” “The traditional stoves would use a cooking gas tank instead of gas pipes nowadays” “The kitchen can have a wall mounted cupboard to store dishes”

“I have an altar for praying.” “Elderlies usually have an altar at home.”

### **5.2.3 Motivation for elderlies**

Some participants have commented that the game will have positive effects for elderlies.

“The exercises performed in the game are quite good for elderlies, they are quite convenient” “The game is good as elderlies need to exercise more.” “Moving my arms like in the game is good; moving my hands like this makes them more flexible”

One participant commented that the game is not fun because the challenges resemble too much with daily activities.

“There is not much fun in the game as it is somewhat the same as what I do at home.”

However, another participant remarked with an opposite opinion that it is engaging because it is similar to daily activities.

“This is more of doing daily activities, use of my hands to exercise. Useful for hands, can exercise.”

#### **5.2.4 Improvement within the game**

Guidance was required for all participants to teach on how to play the game. One of the participants required guiding to perform each action and needed to be informed when a set of actions are completed and a different set of actions to be performed. However, three out of five participants, after being taught and going through two challenges, are able to continue playing the game and proceed to different challenges without additional guidance.

#### **5.2.5 Immersion in the game**

Three of the participants are able to play through the game with a certain degree of immersion. One of the participants listened attentively when explained about the importance of collecting keys for the final challenge. She was able to acknowledge when keys are found and she was progressing. One participant exhibit similar behavior of counting the dishes reducing as she performs in the challenge of cleaning dishes. She recognized the completion of challenge when all the dishes are washed and placed in the drying rack. At finding the first key, she asked for more details such as why the keys are hidden and who hid the keys. Another participant, after going through the first challenge, commented that she realizes the relationship of the upper limb actions and the IADLs performed in the challenges.

### **5.2.6 Emotions exhibited during gameplay**

No participant has exhibited negative emotional traits such as fear, sadness or anger during gameplay.

All participants exhibited the instinct of collecting. This is shown when they recognized that they are collecting keys. Two participants even verbally counted the number of keys they have after completing each challenge. Joy was observed by most after the completion of the game, where they escaped out of the HDB flat. Some exclaimed when the game is completed.

At exhibiting the collecting instinct, participants noted a sense of accomplishment when completing individual challenges (pride) and a sense of joy when finishing the game. Curiosity was voiced out by one participant who asked why they are collecting keys and what caused the keys to be hidden.

Four of the participants identified themselves as the person escaping the game (identification). These participants treated the game avatar as themselves and addressed that they completed the game actions instead of the game's avatar. This could be due to the game being viewed in first person view. There is no exhibition of negative traits of anger by participants; this is emphasized as anger is an emotion linked with identification instinct. As interconnected emotions and instincts can influence each other, the association of the game avatar as participants themselves (identification instinct) might have a positive contribution to the curiosity emotion of participants. This may have

contributed to the pride emotion when completing parts of the challenges as well.

When asked about the items and environment in the game, the participants exhibit joy when communicating about how familiar or different the setting of their home is compared to the game setting.

### **5.2.7 Recognition of goals**

4 out of 5 participants recognized that the goal of the game is a form of exercise beneficial to elderlies. “The exercises performed in the game are quite good for elderlies, they are quite convenient” “The game is good as elderlies need to exercise more.”

Aside from the above goal, participants recognized that the goal within the game is to maintain cleanliness of the home. This goal was determined by all participants during the evaluation. The reason why this goal was determined is most likely because the challenges implemented in ERSR were leant towards Lawton’s Housekeeping IADLs.

Participants further explained that the goal of keeping their homes clean and tidy is important. They both associated this with their home cleanliness and with a general consensus that cleanliness is important for an elderlies’ health and safety. “Because it is home, so it needs to be clean” In addition to recognizing the goal in the overall game, a participant recognizes the goal of cleanliness in specific challenges within the game. The participant said that keeping the bookshelf tidy is important to her because her grandchildren would come and visit and makes a mess after reading.

## **5.3 Lessons learned from the results**

Through the evaluation, we identified several potential barriers and opportunities related to meaning in play and motivation.

### **5.3.1 Conveying meaning in challenges**

It was originally intended to convey the meaning of the challenges through the visuals of the setting and challenges. The result was participants being unclear and even confused of what he should do in the game. In Norman's words, the design of the game needs higher affordance and signifiers to convey what it can do and what the participant needs to perform [43]. The setting in the HDB flat was enough for participants to understand where they are, but the problem of a locked gate and the need of collecting keys was not clear enough.

However, the implementation was able to inform some participants their progression and provide sufficient feedback for their actions after going through the first two challenges with them. It was surprising when some of the participants were able to complete the third challenge and move on and perform the next challenges without our intervention. This suggests that the affordance in the challenges is high enough for players to progress through the game after learning the game's fundamentals but insufficient to teach the game to players.

### **5.3.2 Relationship between immersion and motivation**

It was noticed during our evaluation that participants who were more immersed in the game were more motivated to completing the game and participating in the interviews. Two out of the five participants exhibited positive traits in particular. The participants were proactive in asking for the meaning of performing the challenges and collecting keys. One exhibited satisfaction for completing the challenge of washing dishes. These two participants were keener in giving suggestions during the interviews and the duration of their interviews were longer than the other participants. Both recognized that the challenges are activities similar to daily activities they performed with one declared that it is exactly why it was engaging. They also emphasized the importance of these activities for their own different reasons, e.g. need of cleanliness, in preparation for family visit. In contrary, one participant who explicitly declared the dislike of the game said it was because they are just activities performed daily.

This suggests that participants who view importance in the IADL they performed in real life may be more motivated in completing a game with similar activities. This can be further understood that activities familiar to elderlies need to be significant enough for them in real life to have a bigger effect in immersion and motivation.

### **5.3.3 Meaningful play from goals for IADL-related game challenges**

The goal of maintaining cleanliness was identified by participants during evaluation. As it was initially not prompted to the participants the objective of the game was cleanliness, this can be identified as a self-defined goal by players of the game. To further elaborate, this goal arose when players attempted to find meaning out of a specific set of IADL-related challenges they faced during gameplay. This act of self-defining goals is beneficial to stroke rehabilitation, as identified by Resnick et al, as it increases the sense of ownership and responsibility of stroke recoverees.

The act of defining specific goals related to particular combination of IADL-related challenges by participants opens up the possibility for our implementation to prompt players to define different goals based on different combinations of IADL-related challenges in game. As IADLs comprise of different daily activities with no personal purposes, the goals defined gives a positive personal meaning to these functional activities, such as increase cleanliness of home, making home more accessible, tidying for family visits. This act of giving meaning to player actions is what Salen et al defined as meaningful play.

### **5.3.4 The empowerment through instincts and emotions**

The evoking of identification instinct was noticed during evaluation. In the context of video games, self-identification is an instinct about the tendency of players to adore people of success or fictitious characters and players naturally project themselves as the strong fictitious playable character.

In the context of ERSR, the participants projected themselves to the game avatar in first person perspective. They regarded themselves as the one who were performing the challenges in the game when in actual fact it is the avatar in virtual game space performing these virtual challenges. As ERSR is designed for stroke rehab patients to imitate performing activities of daily living with simplified motor actions, this self-projection can be empowering. It is possible to improve on using this identification instinct to allow patients to associate themselves better with a person who is able to perform activities of daily living successfully, who they aimed to become through rehab.

## **6 Conclusion and Future Work**

This chapter concludes the research together with contributions and future direction of the project.

### **6.1 Contributions**

This research explored the effects of applying familiarity in serious games for stroke rehab. The results have shown that activities familiar and important to elderly have positive effects for motivation.

The implementation framework created broke down the implementation steps of designing a stroke rehab serious game with motivating features. The steps incorporated underlying principles of creating an engaging escape room game in relationship with psychology concepts of familiarity, cognitive flow, and game design principles such as meaningful play and emotion-based game design. The thesis has separated design and implementation into two sections in effort for similar designs to be replicated. By creating a framework with practical steps to design rehabilitative exercises with engagement, we create a tool for rehab practitioners to design engaging rehabilitation consistently.

## 6.2 Conclusion and future directions

In the report of Self-perception of Health among Elderly community dwellers in Singapore, over two hundred elderlies travel out and engage in leisure activities about once a week [47]. These activities have a significant influence in the way subjects perceived health. This indicates a possibility in creating ERSR games beyond the setting of home or indoors. Recent large scale escape room events were held frequently in outdoors locations such as track and field stadiums. This shows that escape room designs are not confined to indoors only.

In future, more devices that increase precision tracking of motion can be incorporated into the game, making it possible to create unique activities for players to interact in the game. In time the exercises will not just limit to upper limb rehabilitation and would be able to incorporate higher precision motions as well.

The relationship between game complexity and progression was not fully tested in the current implementation. Although participants were able to progress smoothly due to the low difficulty barrier, it is still unknown if retention of focus can be maintained for prolonged and repeated gaming sessions. This will be a topic we aimed to find out in future.

Stroke rehabilitation is a time consuming process for which stroke survivors relearn basic living skills. The repetitive nature of the exercises involved in rehabilitation encourages researchers to devise methods that motivate stroke survivors to complete these exercises. The aim of incorporating the concept of escape room in game immersion is one of

the many efforts to prolong immersion and thus increase the frequency of elderly performing stroke rehabilitation via the game.

# Appendix 1

## The Lawton Instrumental Activities of Daily Living Scale

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### A. Ability to Use Telephone

1. Operates telephone on own initiative; looks up and dials numbers..... 1
2. Dials a few well-known numbers..... 1
3. Answers telephone, but does not dial..... 1
4. Does not use telephone at all..... 0

### B. Shopping

1. Takes care of all shopping needs independently..... 1
2. Shops independently for small purchases..... 0
3. Needs to be accompanied on any shopping trip..... 0
4. Completely unable to shop..... 0

### C. Food Preparation

1. Plans, prepares, and serves adequate meals independently..... 1
2. Prepares adequate meals if supplied with ingredients..... 0
3. Heats and serves prepared meals or prepares meals but does not maintain adequate diet..... 0
4. Needs to have meals prepared and served..... 0

### D. Housekeeping

1. Maintains house alone with occasion assistance (heavy work)..... 1
2. Performs light daily tasks such as dishwashing, bed making..... 1
3. Performs light daily tasks, but cannot maintain acceptable level of cleanliness..... 1
4. Needs help with all home maintenance tasks..... 1
5. Does not participate in any housekeeping tasks..... 0

### E. Laundry

1. Does personal laundry completely..... 1
2. Launders small items, rinses socks, stockings, etc..... 1
3. All laundry must be done by others..... 0

### F. Mode of Transportation

1. Travels independently on public transportation or drives own car..... 1
2. Arranges own travel via taxi, but does not otherwise use public transportation..... 1
3. Travels on public transportation when assisted or accompanied by another..... 1
4. Travel limited to taxi or automobile with assistance of another..... 0
5. Does not travel at all..... 0

### G. Responsibility for Own Medications

1. Is responsible for taking medication in correct dosages at correct time..... 1
2. Takes responsibility if medication is prepared in advance in separate dosages..... 0
3. Is not capable of dispensing own medication..... 0

### H. Ability to Handle Finances

1. Manages financial matters independently (budgets, writes checks, pays rent and bills, goes to bank); collects and keeps track of income..... 1
2. Manages day-to-day purchases, but needs help with banking, major purchases, etc..... 1
3. Incapable of handling money..... 0

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**Scoring:** For each category, circle the item description that most closely resembles the client's highest functional level (either 0 or 1).

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## Appendix 1: The Lawton Instrumental Activities of Daily Living Scale

# Appendix 2

## Appendix 2: Interview procedure, questions and consent form

### **Procedure:**

Testers play the game with 6 different game actions to perform. The duration is expected to be between 10 - 15 minutes. Minimal guidance and interference will be injected. The tester is then surveyed with questions related to the game and his personal opinion on familiarity and engagement.

### **Semi-structured Interview Questions:**

- Age:
  1. Where does the setting resemble? Compared to your home, what is alike and unlike?
  2. What daily activities do you perform at home? Are they similar to the ones in the game? What are alike and unlike?
  3. Are there any elements in the game that interests you? What do you like or dislike?
  4. What is your suggestion to improve the experience?

## Consent Form

### Evaluating Serious Game for Stroke Rehabilitation

Please tick accordingly:

- I understand that screen recordings, which do not include human subjects, may be taken during the study. These recordings may be used in future publication.
- I have been told of the confidentiality of information collected for this project and the anonymity of my participation.
- I acknowledge that I can withdraw from this study at any point in time by informing the researcher on site or the Principal Investigator and all my data will be discarded.
- I have been given satisfactory answers to my inquiries concerning study procedures and other matters.
- My signature below is my acknowledgement that I have agreed to participate in this study according to the above-mentioned terms. I agree that any information obtained from this research may be used in any way thought best for this study.

SIGNATURE:

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NAME:

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DATE:

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