

# Serious Game Design for Stroke Rehabilitation

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## Abstract

Stroke rehabilitation is a challenging process which requires intensive treatments. In order to help stroke patients relearn basic skills, 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.

**Keyword:** Stroke rehabilitation, Game design, Familiarity.

## **I. Introduction**

Rehabilitation serious game 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 video game 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, 10]. 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 [28].

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 [15]. 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 [8].

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. There are certainly stroke rehabilitation targeted serious games researched, such as Balaam et al. [3] and Anderson et al. [2], incorporating motivation based on game design theories. However, these researches have not created actionable frameworks to replicate their success in designing serious games. Our research 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. In addition, we design and develop a working game demo of an Escape Room for Stroke Rehabilitation (ERSR) with natural interface devices such as Microsoft Kinect and Leap Motion's sensor controller. The effects of familiarity, emotional and goal driven design are also been studied in this rehabilitation game to enhance the patients' motivation.

## **II. Related Work**

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

### ***A. Motivation in rehabilitation games***

The use of gamification for rehabilitation has shown a degree of success to enhance the patients' motivation and engagement. Shah et al. implemented a set of stroke rehab games designed with functional tasks and instinctive movements [24]. Scoring mechanism together with small rewards and punishment systems were built into their games to motivate players in performing better. The research by Burke et al incorporated game design theory of meaningful play into rehabilitation [5]. Borghese et al. also implemented meaningful play in the framework of their minigames [4]. Lohse et al. suggested that applying games into rehabilitation is an interdisciplinary approach involving different components [14]. They took a unique approach to integrate game design, motor learning and neurophysiology changes with rehabilitation science. Flores et al. listed a set of gaming design criteria for stroke rehabilitation programs and criteria for elderly entertainment [7]. The list includes providing meaningful tasks, appropriate cognitive challenges and motivational feedback. They proposed that fulfilling a higher number of the criteria can produce a serious game with elderly players' 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 [10]. A similar application of daily activities was found in design of Sadihov et al. [22]. 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.

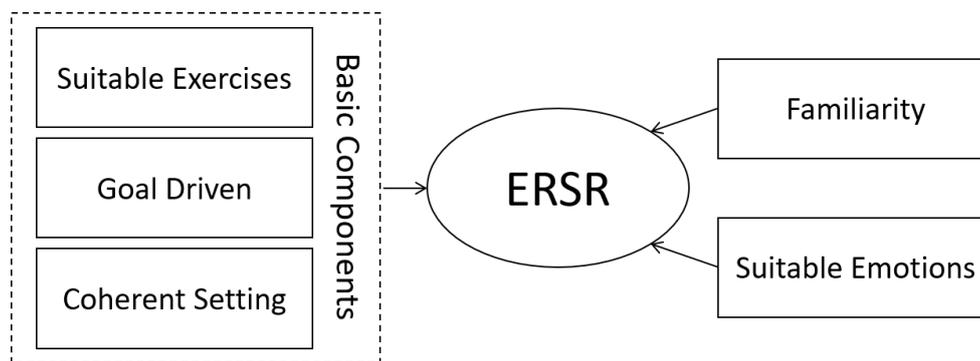
### ***B. Escape Room Games***

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 [21]. 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. 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 [11]. In the game, the player needs to work his way to escape through solving puzzles which incorporates electromagnetism concepts. 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.

## **III. Designing ERSR**

In this section, we propose on how to redesign Escape Room for meaningful Stroke Rehabilitation (ERSR). Based on the design concepts suggested by Nicholson [16], we propose a design framework for creating meaningful and engaging serious games for stroke patients using escape room. In our framework (Figure 1), the creation of an escape room suitable for stroke rehabilitation depends on

the five elements around it. Suitable exercises are to be selected for the patients. Based on the exercises, game challenges which are goal driven needs to be created with a game setting coherent to the challenges. Familiarity is applied to help the elderly understand the games. Meanwhile, 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.



**Figure 1 ERSR design framework**

### ***A. Basic components of ERSR***

The purpose of rehabilitation 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. In order to be effective, efficient and safe for the patients, the 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.

The research focuses 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 [13]. This is suitable as escape room games focus on upper limb actions as well.

As one of the widely recognized and clinically relevant measures of body function impairment

after stroke, 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 [9].

Extracting from FMA, 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.

Rehabilitation exercises defined for ERSR must be within the above movements and follow the aforementioned exercise characteristics. Goals of a stroke patient are important in creating an effective stroke rehabilitation. A study by Resnick et al. was conducted to understand the relationship between elderly's motivation and improvement of function [19]. 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 [17]. 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 [23]. 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.

## ***B. Familiarity design in ERSR***

A common issue of modern technology is that technologies such as games can be difficult for elderly to use. This is often because they are not designed around the understanding of elderly. What most users of technologies assumed to be natural affordance may not accurately interpreted by elderly [27]. Familiarity helps in encouraging the elderly to learn and understand how to interact with the new technology by using their existing knowledge learned in their everyday life. Moreover, good familiarity design can evoke the elderly's memories and corresponding emotions [20]. In the previous research, three dimensions of familiarity elements should be satisfied [30]:

- **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, ERSR widely incorporate actionable familiarity in their design. In escape room game, it is set in a room with items commonly found in a bedroom, such as a bed and windows. 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 the elderly to evoke symbolic and cultural familiarity, challenges in ERSR will be able to achieve all three elements of familiarity.

In order to create a coherent experience familiar to the elderly, the setting must be within the same context as the game challenges. This means there must be a reason for elderly to perform the challenges in the provided setting. Tsoupikova et al. created a game in the context of a tea

party [26]. 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 [25]. 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.

### C. Evoking emotions through design

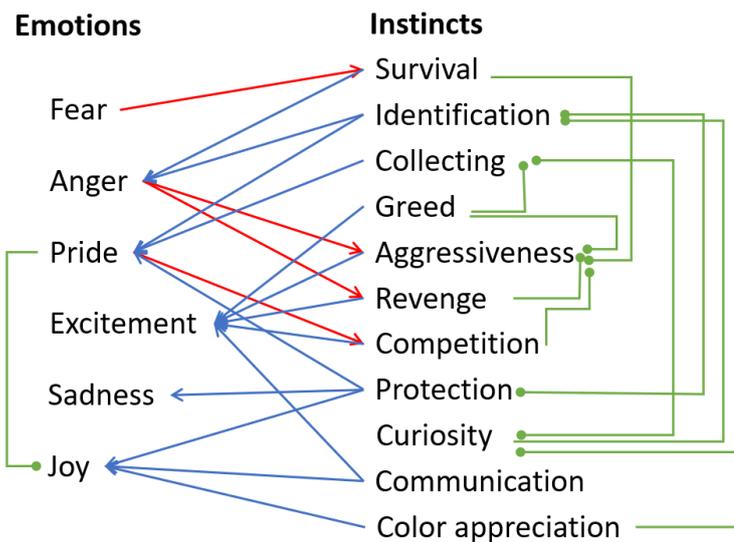


Figure 2 Main relationship between basic emotions and instincts

Emotions of stroke patients play a large role in rehabilitation. For example, fear is one of the emotions that can cause patient’s resistance to rehabilitation. In Resnick’s research [19], 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 room games, our aim is to

create a game which elderly patients feel safe and is willing to participate in rehabilitation 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 [6] to structure basic emotions and instincts evoked by humans when they play. The 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 2). 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. 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.

#### IV. Implementation of ERSR

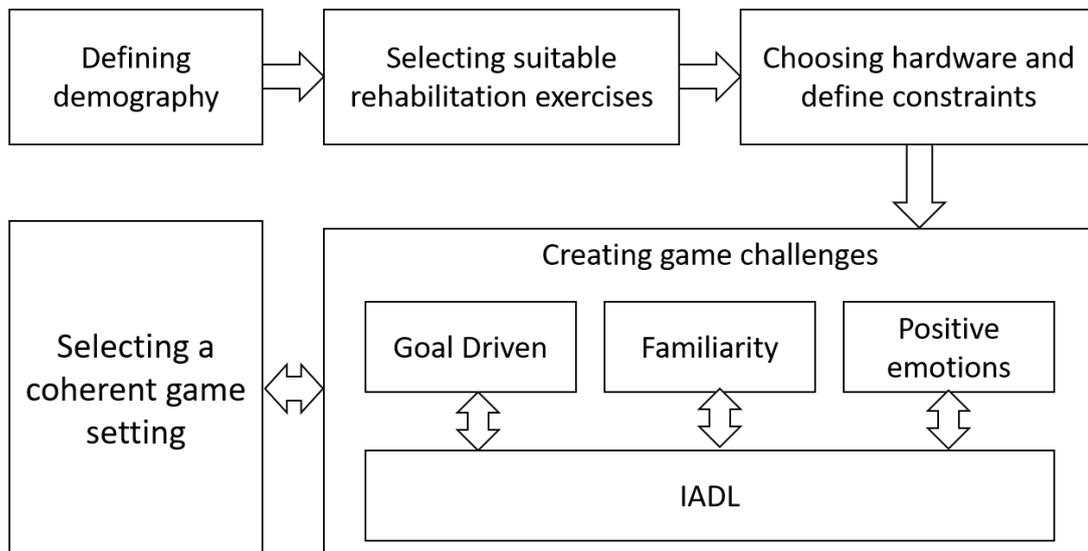


Figure 3 ERSR implementation framework

Figure 3 shows the framework of ERSR implementation. The framework begins with understanding the demography of the elderly patients. This includes understanding what the elderly performs daily,

their preferences and habits. Suitable rehabilitation 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 exercises and hardware, while ensuring that they are goal driven, familiar and possess positive emotions for the demography of the elderly. Lastly, the game setting must be coherent with the challenges to make a coherent experience throughout the game.

Applying the design framework, we implemented a prototype of ERSR. In reality, selecting of the rehabilitation actions should be suggested 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 selected to match with the motor activities based on the similarity. The stroke patient's demographic is then considered in planning the game's setting and possible game actions. Our implementation aims to target the common Singapore's stroke sufferers. Based on the data of stroke patients from [18], we select a range of 50 to 65 years old elderly Singaporeans of both genders to be our users for this implementation. Rehabilitation exercises for ERSR must be within the five sets of upper limb movements and follow the characteristics in 3.A. We looked into different upper limb rehabilitation protocols to find exercises with elaborate and repetitive characteristics. In order to detect the upper limb movements, the Kinect V2 is chosen to detect shoulder and elbow movements and the Leap Motion is chosen as an additional device to provide additional support to wrist and hand movements detection. The combination of these two devices allows for the coverage of all 5 sets of upper limb movements identified.

### ***A. Decisions of challenges***

Games have long term and short term goals. This is equivalent to rehabilitation 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 [19]. 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 (IADL). 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 IADL. The escape room genre is recognizable to set in a daily living setting with intractable daily living objects. For example, some escape rooms are set in a bedroom with daily objects like a bed, windows and cupboards. The use of IADLs is used in other serious game designs as well. Mentioned in Section 2, Hondori et al used tasks of daily life in their game design [10]. They noticed that patients gained confidence in performing real activities by practicing similar virtual activities during therapy. Sadihov et al. designed one of their games as wiping table, as exercises performed in the conventional therapy are often based on IADL [22].

**Addressing familiarity.** The challenges using IADL must fulfill the three familiarity characteristics to be effective in invoking familiarity with elderlies. As our targeted demographic are elderly Singaporeans, we select a set of IADL 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 [12]. 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.

**Complexity of challenges.** In designing meaningful challenges, Nicholson states that a balance is required for physical effort and mental inspiration to solve [16]. This means that the puzzle element in challenges must not be so complex that cause player frustration. Another design

aspect proposed by Nicholson is having clear solution for puzzles [16]. Having a clear goal is also supported by Lohse et al, who stated that goals can lead to a higher chance of acceptance [14]. These design aspects and the requirements of rehabilitation drove our decision to remove puzzle elements from this implementation. In our designed rehabilitation 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 IADL with fixed repetitions. Movements are performed without any time limit and there is no failure of challenges.

**Planning the puzzle path.** Referencing from Wiemker et al.'s design of escape rooms [29], 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. 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 rehabilitation, as it allows patients to focus on each 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.

**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 2). 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.

### ***B. Selecting the game setting***

In the section above, we have established that the IADL 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) [12]. 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, a design prevalent in that particular time of Singapore is shown in Figure 4.



**Figure 4 A 3-room flat 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 5). Furniture and household items are created for placing items for different challenges. As the game setting is a natural location for the elderly to perform IADL, 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.



**Figure 5 Implementation of ERSR game setting.**

### ***C. 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 IADL are complex actions requiring combined upper limb movements, to match with our upper limb isolated movements, we selected suitable IADL 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 IADL in consideration of actionable familiarity. 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 rehabilitation.



**Figure 6 Heads on display 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 6). 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.

**Clearing the table.** The clearing the table challenge is categorized under housekeeping in Lawton's IADL. The challenge requires player to perform the shoulder adduction action. 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 7).

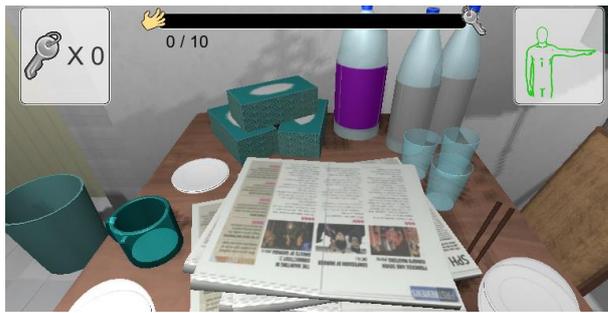


Figure 7 Clearing the table in ERSR



Figure 8 Tidying book shelf in ERSR

**Tidying bookshelf.** The tidying book shelf challenge is categorized under housekeeping in Lawton's IADL. The challenge requires player to perform the shoulder flexion action. 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 8).

**Hanging laundry.** The hanging laundry challenge is categorized under laundry in Lawton's IADL. Similar to tidying book shelf, the challenge requires player to perform the shoulder flexion action. 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 9).

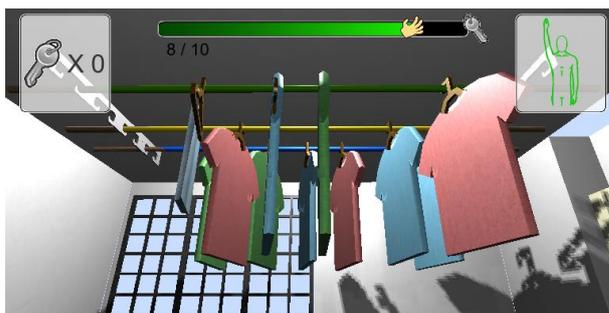


Figure 9 Hanging laundry in ERSR.



Figure 10 Washing dishes in ERSR.

**Washing dishes.** The washing dishes challenge is categorized under food preparation in Lawton's IADL. The challenge requires the player to perform the elbow flexion action. 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 10).

**Switching television channels.** Switching television channels does not belong in any Lawton's IADL. 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. 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 11).



Figure 11 Switching television in ERSR.



Figure 12 Opening lock in ERSR.

**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. 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 12).

## V. Evaluation of ERSR

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.

### ***A. Familiarity design***

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.

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.”

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.”

### ***B. Motivation for the elderly***

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.

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.”

### ***C. 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.

#### ***D. Recognition of goals***

Four out of five 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 learned 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 a general consensus that cleanliness is important for elderly's 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.

## **VI. Conclusion**

This research explored the effects of applying familiarity in serious games for stroke rehabilitation. The results have shown that familiar activities is important to the elderly have positive effects for motivation. The implementation framework created broke down the steps of designing a stroke rehabilitation 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 research has separated design and implementation into two sections in effort for similar designs to be replicated. Lastly, we invited five elderly participants to test our designed ERSR, their positive feedback reflects the effectiveness of our framework.

## **Acknowledgement**

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