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DESIGN OF A MOBILE GAME APPLICATION TO SUPPORT HAND REHABILITATION OF STROKE PATIENTS IN INDONESIA

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ABSTRACT

Stroke is a leading cause of death in Indonesia. A stroke can paralyze multiple parts of an individual's body, including the hand. While therapy for stroke rehabilitation should be done repetitively over a long period of time, some stroke patients do not have adequate access to conduct therapy in a rehabilitation centre. Therefore, this research focuses on the design of a mobile game application as an alternative therapy to support hand rehabilitation for stroke patients. Our research applied the interaction design lifecycle model, which consists of the process of identifying the needs, designing the concept based on user needs, building a prototype based on the design concept, and evaluating the prototype with stroke patients, as the potential users, and a doctor who is an expert in stroke rehabilitation. The evaluation results show that stroke patients can interact well with the designed mobile game application, and they felt that the game was a good exercise tool for them to use as part of their stroke therapy.

Keywords: Design; Hand rehabilitation; Mobile game; Stroke

1. INTRODUCTION

Stroke is a disease that causes most deaths in Indonesia. Researchers from the Institute for Health Metrics and Evaluation (IHME) at the University of Washington identified stroke as the leading cause of death in Indonesia in 2013, with 289,917 deaths attributed to stroke, based on research by the Global Burden of Disease Study 2013 (Adystiani, 2014). When a person suffers a stroke, a blockage or rupture of blood vessels in the brain causes a sudden interruption to the blood supply to a part of the brain, with some brain cells dying (Rijal, 2015). There are two possible impacts experienced by persons suffering from a stroke. The worst outcome is death, while the other outcome is a very severe disability which requires a long-term care (Syah, 2014). Due to current advances in medical technology, a greater number of stroke patients than ever escape death and may instead live with disabilities (Wirawan, 2009).

Based on an interview we carried out with a doctor specializing in physical medicine and rehabilitation at Hasan Sadikin Hospital Bandung, one part of the body that is often affected by stroke is the hand, including the fingers and wrist. Patients who have disabilities in their hand will experience challenges with fine motor control of the impacted hand, lack of strength in the arm, and hand movements which make it difficult to perform daily activities such as bathing and dressing; these individuals may not able to live independently and work productively. The hand disability caused by the damaged nerves of stroke patients is not easily recoverable. Therapy treatments for hand rehabilitation should be followed repetitively over a long period of

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time. However, some stroke patients do not have adequate access to therapy in a rehabilitation centre.

Several prior studies have explored the use of games as tools for stroke rehabilitation. Anna (2012) identified a new form of stroke rehabilitation therapy recommended by experts using Nintendo Wii games, which utilize a motion sensor and require patients to move in order to play the game (Figure 1). Besides the Nintendo Wii games specifically, there are other motion-based video games used for stroke rehabilitation. This so called motion-controlled gaming system, is a type of game that can guide stroke patients to interact with the system through bodily movements combined with voice commands, natural real-world actions, and movement recognition (Figure 2).

Figure 1 Stroke rehabilitation using Nintendo Wii (Candra, 2014)

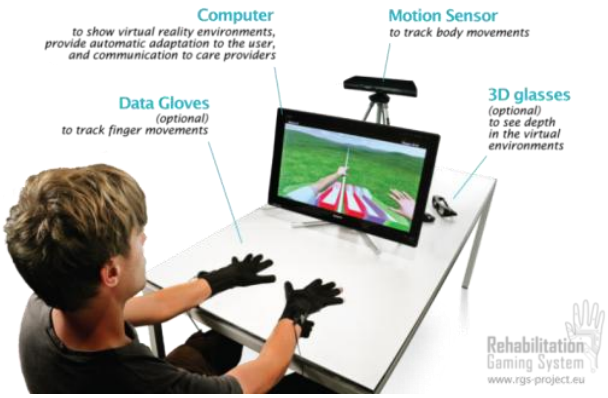

Figure 2 Stroke rehabilitation using motion-based video games (Team, 2014)

Both of these studies provide examples of games being used to support the rehabilitation of stroke patients in a home setting, which is generally installed at one place in patients' homes during their rehabilitation process. However, the daily activities of stroke patients may not be limited to or centralized in one location. The idea behind our research is to design a mobile game application for stroke rehabilitation that can be used anywhere the patient goes in order to support rehabilitation in a mobile setting. Moreover, the mobile game application will be dedicated to training the affected hand of stroke patients to aid in strengthening the body part most needed to perform many daily activities. The design of this mobile game application is intended to be exciting and fun, so that stroke patients do not feel bored in spite of the nature of repetitive and long rehabilitation therapy exercises.

2. METHODS

2.1. Participants

Three stroke patients and one doctor specializing in physical medicine and rehabilitation were involved throughout the design process. All patients met the following criteria: (i) a score on the Manual Muscle Test (MMT) equal to or more than (≥) 2; and (ii) a score on the Mini Mental State Examination (MMSE) equal to or more than (≥) 24. The Manual Muscle Test (MMT) is a measure used by doctors and therapists to determine how much power a patient has in a single body part (Silvia, 2015). The Mini Mental State Examination (MMSE) is a measure used to systematically determine a person's mental status in order to distinguish between stroke patients who have do and do not have cognitive disorders (Kurlowicz & Meredith, 1999). Table 1 shows the profiles of the three stroke patients participating in this research.

2.2. Procedure

The Interaction Design Lifecycle Model will be applied to direct the design process of a mobile game application to support the hand rehabilitation of stroke patients. Using this approach, the stroke patients, as potential users of the mobile game application, will be invited to participate in the design process. User involvement is needed to determine the actual needs of stroke patients so that the designed mobile game application will be able to meet their rehabilitation therapy needs. The design stages include the identification of needs, the development of the concept, the making of a prototype, and the evaluation of the prototype (Preece et al., 2011).

Table 1 Profile of participants

No.	Age (years)	Period since suffering stroke	Cause of stroke	MMSE score
1	45	2 years	High cholesterol. There is a blockage in the right brain, resulting in left side paralysis. One year after suffering the stroke, she fell and fractured her left arm; she does not dare to do any exercises or therapeutic practices that she feels are too extreme.	29
2	76	4 months	There is a blockage in the right brain, resulting in left side paralysis.	28
3	64	5 years	Experienced stiffness in the mouth in 2008 and managed to recover in 4 days but he did not taking the medicine routinely so he had another stroke attack.	30

3. RESULTS

3.1. Needs Identification

The identification of needs was conducted through observation and interviews with three stroke patients. In addition, we also interviewed one doctor specializing in physical medicine and rehabilitation. Table 2 provides a summary of the results from the observation and interviews with stroke patients. We developed our interpretations of user needs based on the remarks given by participants concerning the mobile game design (Table 3). These interpreted needs were further grouped into a hierarchy of needs (Table 4) based on Ulrich and Eppinger (2012), by categorizing the needs on the basis of similarity.

From the interview with the doctor, we learned that stroke patients must rehabilitate the body parts affected by stroke routinely and repetitively. Exercises should be designed to accurately target the training of the joints of stiffened hands.

Table 2 Observation and interview results from patients

Participant No.	Observation	Remarks concerning the mobile game design
1	Female patient was able to sit and stand with the help of others as well as with the aid of tools. After doing therapy exercises several times, she believed that exercises for healing her foot were working faster than those for healing her hand.	*"do not be too complicated"* *"which are fun"* *"rather see a bright colour"* *"I need to practice my finger."* *"Actually, I do not like playing with a gadget."*
2	Female patient was able to sit and stand with the help of others as well as with the aid of tools. She likes sports. After doing therapy exercises several times, she believed that the exercises for healing her foot were working faster than those for healing her hand. She needs to exercise her hand more routinely in order to heal her hand.	*"want a quick cure"* *"not difficult"*
3	Male patient who suffered paralysis on the left side of the body. He was able to sit and stand without help but needed a rather long time to do so. After doing therapy exercises several times, he believed that the exercises for healing his foot were as fast as those for healing his hand.	*"which are easily understood"* *"not boring"*

Therefore, knowledge of the expected range of motion of the hand is required. In addition, the mobile game application should also be accessible to stroke patients who have paralysis in either the left or the right hand. The condition of the patient's hands, as they recover, will further increase their independence and improve their quality of life. The summary of the needs identification from both patients and doctor can be seen in Table 5.

Table 3 Needs interpretation

No.	Participant's remarks	Interpreted needs
1	*do not be too complicated*	The game has a concept that is easily understood
2	*which are fun*	The game has a training concept that is not as boring as the rehabilitation therapy in hospital
3	*rather see a bright colour*	The game has a clear and bright display
4	*I need to practice my finger.*	The game has a concept of repetitive exercises for hands
5	*Actually, I do not like playing with a gadget.*	The game is created with a clear command or symbols
6	*want a quick cure*	The game has a concept to train joints in the right hand
7	*not difficult*	The game is made with way of playing that is not complicated
8	*which are easily understood*	The game uses Indonesian language to make it easily understood
9	*not bored*	The game has a specific goal so that the user feels challenged

Table 4 Hierarchy of user needs

No.	Grouped needs	Interpreted needs
1	*The game can be operated easily*	The game has a concept that is easily understood
		The game is created with a clear command or symbols
		The game is made with way of playing that is not complicated
		The game uses Indonesian language to make it easily understood
2	*The game can be a therapeutic tool that provides efficient result*	The game has a concept of repetitive exercises for hands
		The game has a concept to train joints in the right hand
3	*The game can be played with fun*	The game has a training concept that is not as boring as the rehabilitation therapy in hospital
		The game has a specific goal so that the user feels challenged
4	*The game has a clear and bright display*	The game has a clear and bright display

Table 5 List of identified needs

No.	Source of needs	Identified needs
1	Stroke patients	*The game can be operated easily*
		The game can be a therapeutic tool that provides efficient result
		The game can be played with fun
		The game has a clear and bright display
2	Doctor	*The game uses motion therapy referring to daily activities using hands*
		The game can make patients to exercise repetitively
		The game can be an alternative therapy for stroke patients who suffered paralysis in both hands

3.2. Concept Development

Based on the list of identified needs, we developed the design concept conceptually by first thinking about the function of the mobile game application and secondly by developing the physical design. We developed the mobile game application to be played using a tablet, and the concept we created is designed to fit the screen size of iPad Air 2 (9.7 inches).

Our mobile game application to support hand rehabilitation of stroke patient consists of four mini-games: *Choosing Ingredients* (Memilih Bahan Makanan), *Making Hamburgers* (Membuat Hamburger), *Making Drinks* (Membuat Minuman), and *Setting the Table* (Menata Meja). The game can be played in either Full Mode, in which the player plays all the games, or Practice Mode, in which the player chooses only one game to play.

The game *Choosing Ingredients* is designed to train the wrist of the patient. The player is asked to select groceries that appear on the screen using the closest finger without moving the end of the palm of their hand, which is placed on the bottom of the tablet. Stroke patients can train their wrist by moving their hand to the right or to the left.

The game *Making Hamburgers* is designed to train any of the patients' fingers that have stiffness. This game involves only moving two fingers of one hand in every movement. The first movement is flexion; players grab bread onscreen by closing the thumb and the forefinger. The next movement drags the flexed thumb and index finger in the direction of the arrow

shown, moving bread toward a cutting board. The final movement is extension; the player opens the thumb and the forefinger so that the bread can be placed onto a cutting board. The game *Making Drinks* has a concept similar to *Making Hamburgers*, except this game uses three fingers instead to grab, drag, and place the ingredients into a glass to make a beverage. Likewise, in the game *Setting the Table*, patients use all five fingers to grab, drag, and put materials (tablecloth, hamburger and drink) onto the top of table.

Before prototyping the concept further, we discussed this concept with a doctor who is an expert and has plenty of experience in stroke rehabilitation. We made several design changes to the prototype by incorporating the feedback gained from the doctor (Table 6).

Table 6 Changes of design concept

No.	Concept Elements	Changes
1	First game	In the initial concept, stroke patients only needed to select any groceries that appeared. Based on the feedback from the doctor, we added a movement; after selecting the groceries that appear, stroke patients need to slide the groceries to the left or right so that the patient's wrist is also engaged in the movement.
2	Second game	In the initial concept, only five objects were used for preparing hamburgers. Based on the feedback from the doctor, we increased the number of ingredient to 8 so that each finger performs the same movement twice.
3	Concept of time calculation	In the initial concept, the length of play was calculated so that patients could play the game indefinitely. Based on the feedback from the doctor, the length of play is limited by a specified time so that patients' performance will be measured by the number of objects that they produce.
4	Selection of right and left hand	In the initial concept, there was no option for patients to choose between using the right or left hand to perform the therapy. Based on the feedback from the doctor, there is an option provided so that the patient can perform the exercise on the hand that needs to be trained.

3.3. Making the Prototype

Based on the design concept which incorporates the doctor's feedback, we built a prototype so that the participants could experience using the mobile game application as part of their stroke rehabilitation therapy and be able to further evaluate it. Figure 3 shows the opening of the game, which consists of the title screen and the option to select which hand the patient would like to train. Figure 4 shows the screen where the patients can choose the games they would like to play. They can select between playing all the games in Full Mode and selecting one of four mini-games to play. Moreover, there is a button titled *"Riwayat Permainan Sebelumnya"* in this screen, which players can use to view their history and measure their performance by comparing the result of their current play with the previous play.

Figure 5 shows the screens from the first game "Memilih Bahan Makanan" *(Choosing Ingredients)* which consist of its title and a start button. Patients are asked to choose an ingredient by touching any groceries that appears on the screen using the closest finger without moving the heel of the palm of their hand, which is placed firmly on the bottom of the tablet.

Figure 3 Opening of the game: *Title* (left) and *Selection of hands* (right)

Figure 4 Selection of games

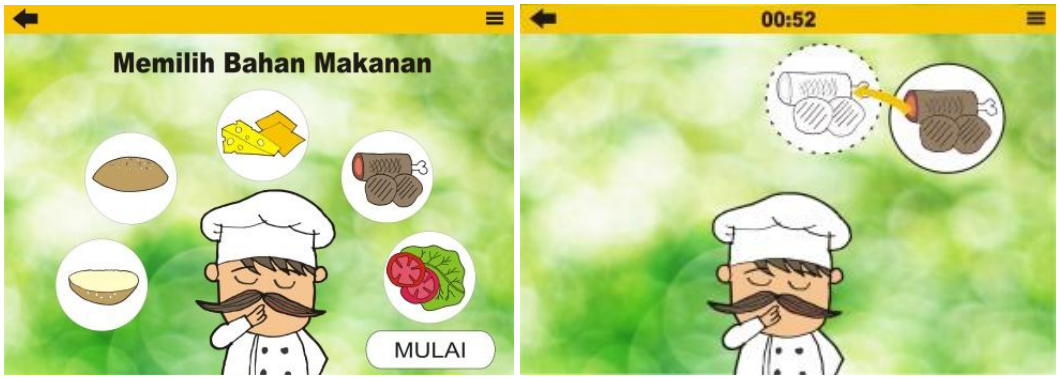

Figure 5 "*Choosing Ingredients"* title page (left); Moving the ingredient (right)

Figure 6 *"Making Hamburgers"* title screen

Figure 6 shows the title screen of the second game "Membuat hamburger" *(Making Hamburgers)*. Figure 7 shows the user interaction of the second game, which moves two fingers of one hand in every movement. The first movement grasps bread by closing the thumb and the forefinger. The next movement drags the thumb and the index finger in the direction of the arrow shown. The final movement opens the thumb and the forefinger so the bread can be placed onto a cutting board. In this game, there are eight types of ingredients to move to the cutting board using different fingers (Table 7).

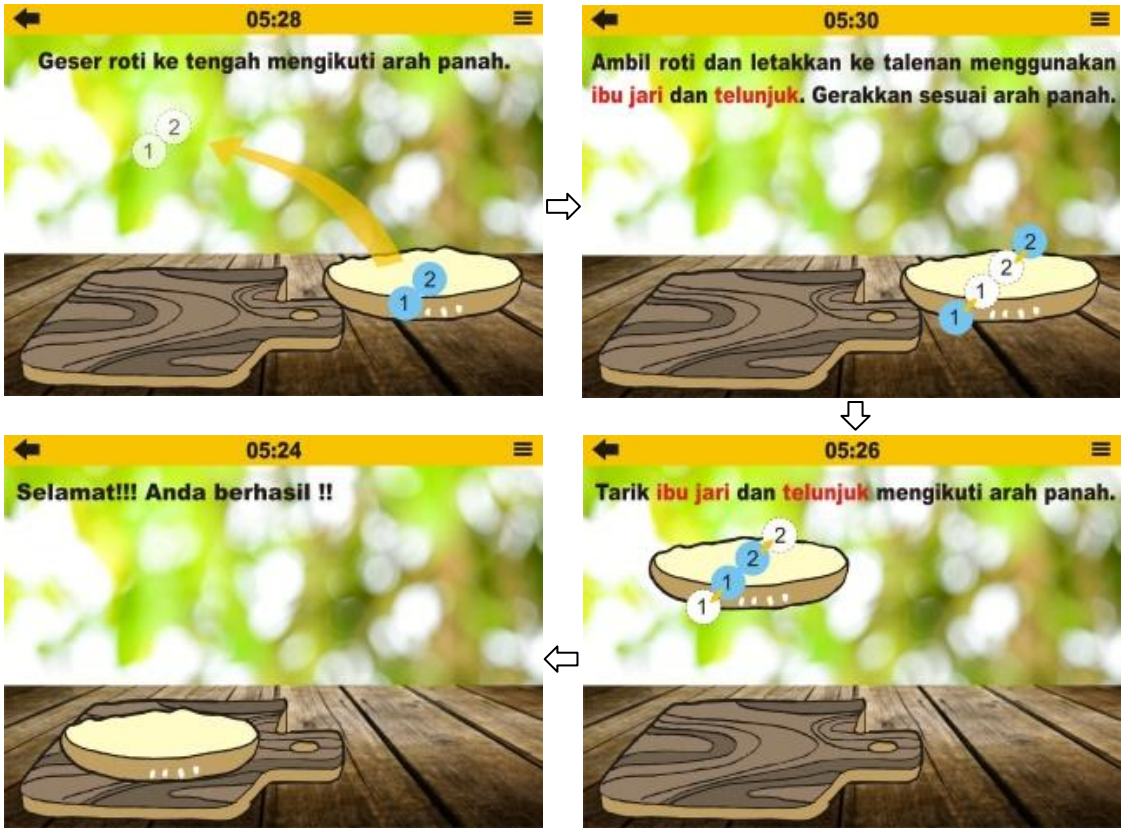

Figure 7 "*Making Hamburgers"* moving the ingredient (clockwise from upper left)

Figure 8 shows the title screen of the game "Membuat Minuman" *(Making Drinks)*. Figure 9 shows the user interaction of the third game, which uses three fingers of one hand in every movement to grab, drag, and put the ingredients into a glass to make a beverage. In this game, there are five types of ingredients that should be moved to a glass with different fingers (Table 8).

Table 7 Fingers trained in the second game

No.	Type of Ingredients	Trained Fingers
1	Bottom bread	Thumb and forefinger
2	First meat	Thumb and middle finger
3	First cheese	Thumb and ring finger
4	Middle bread	Thumb and pinkie
5	Second meat	Thumb and pinkie
6	Second cheese	Thumb and ring finger
7	Lettuce and tomato	Thumb and middle finger
8	Upper bread	Thumb and forefinger

Figure 8 *"Making Drinks"* title screen

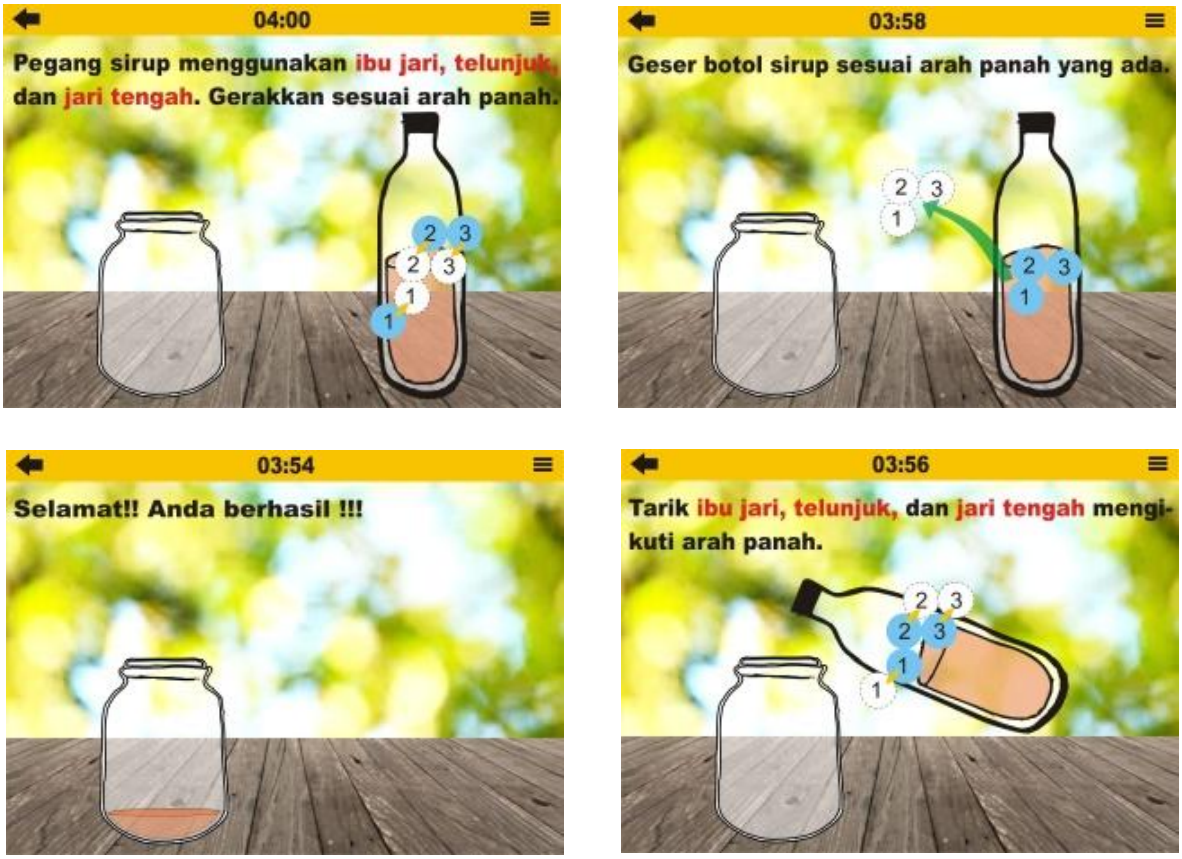

Figure 9 *"Making Drinks"* moving the ingredient (clockwise from upper left)

Table 8 Fingers trained in the third game

No.	Type of Ingredients	Trained Fingers
1	Syrup	Thumb, forefinger, and middle finger
2	Water	Thumb, middle finger, and ring finger
3	Lemon	Thumb, ring finger, and pinkie
4	Ice cubes	Thumb, middle finger, and ring finger
5	Strawberries	Thumb, forefinger, and middle finger

Figure 10 shows the title screen of the fourth game "Menata Meja" *(Setting the Table)*.

Figure 10 *"Setting the Table"* title screen

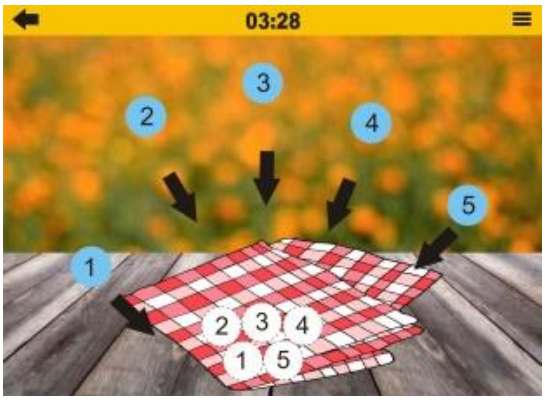

Figure 11 "*Setting the Table"* opening the tablecloth onto the table (clockwise from upper left)

Figure 11 shows the user interaction of the fourth game, which requires players to move all five fingers of one hand in every movement to grab, drag, and place materials (tablecloth, hamburger and drink) onto the top of the table.

3.4. Evaluation of the Prototype

After the prototype was complete, the prototype was shown to a doctor specializing in physical medicine and rehabilitation at Hermina Hospital Bandung to obtain her feedback on the prototype. She thought the prototype that was built had many helpful attributes in accordance with the design concept, and she included feedback during the concept development stage. However, the mobile game application shown to this physician was built as a low-fidelity prototype which differed from a real working application.

The prototype evaluation was also carried out through the observations of stroke patients interacting with the prototype simulated as part of their rehabilitation therapy. From the evaluation process, we learned that the patients can interact with the prototype and play all four mini-games quite well with no major difficulties; they also liked the mobile game application and thought that it could support their hand rehabilitation very well. However, we also observed that the performance of patients, based on the number of items they manage to successfully interact with, quite differs in using the mobile game application. This was expected due to the differences in the level of stroke impact and hand disability. Overall, the patients responded enthusiastically to the idea that the mobile game application evaluated may be part of the daily exercise for their hand rehabilitation therapy. They felt the games challenged them to optimize the use of the hand in need of training while playing in their spare time as part of their rehabilitation.

4. CONCLUSION

This research focuses on the design of a mobile game application as an alternative therapy to support hand rehabilitation for stroke patients. Through applying the interaction design lifecycle model, we have identified the user needs of the mobile game application, designed a concept based on the list of user needs, built a prototype based on the design concept, and evaluated the prototype with three stroke patients as its potential users and a doctor with expertise in stroke rehabilitation. The results of the evaluation show that the stroke patients can interact well with the mobile game application, and they felt that the games challenged them to train their hand. Thus, the mobile game application was an effective exercise tool for them to use as part of their stroke rehabilitation therapy.

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