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Developing and Evaluating Creativity Gamification Rehabilitation System: The Application of PCA-ANFIS Based Emotions Model

Chung-Ho Su
Shu-Te University, TAIWAN (R.O.C.).
Ching-Hsue Cheng
National Yunlin University of Science and Technology, TAIWAN (R.O.C.).

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This study aims to explore the factors in a patient's rehabilitation achievement after a total knee replacement (TKR) patient exercises, using a PCA-ANFIS emotion model-based game rehabilitation system, which combines virtual reality (VR) and motion capture technology. The researchers combine a principal component analysis (PCA) and an adaptive network-based fuzzy inference system (ANFIS) to present a predicting, artificial emotion model with a Plutchik emotional wheel in a 3D Gesture gamification rehabilitation system, and illustrate the value of the Plutchik emotional wheel. Also, this study tries to improve a rehabilitant's self-efficacy, based on interesting games and the use of Kinect technology to capture a rehabilitant's motion. This quasi-experimental design required two months to collect the PRS rehabilitation treatment data from the study's participants, who were divided into experimental and control groups. The experimental group, rehabilitated with a PRS, filled out a questionnaire and evaluated whether the system operations and self-efficacy changes affected their rehabilitation achievement. These findings could be referenced for related researchers designing auxiliary tools and for helping physical therapists improve rehabilitants' performance. Meanwhile, these findings recommend that patients have the operation in the early stages and that they form regular exercise habits for a better rehabilitation outcome.

Keywords: game-based rehabilitation, ANFIS Emotion Model, remote home care, 3D Gesture rehabilitation System

Correspondence: Ching-Hsue Cheng,
Department of Information Management, National Yunlin University of Science and Technology, Yunlin County, Douliu City, 640 Taiwan (R.O.C.).
E-mail: chcheng@yuntech.edu.tw

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INTRODUCTION

State of the literature

- Combine a principal component analysis (PCA) and an adaptive network-based fuzzy inference system (ANFIS) to present a predicting, artificial emotion model with a Plutchik emotional wheel.
- Improving a rehabilitant's self-efficacy, based on interesting games and the use of Kinect technology to capture a rehabilitant's motion.
- Findings recommend that patients have the operation in the early stages and that they form regular exercise habits for a better rehabilitation outcome.

Contribution of this paper to the literature

- Proposed a gamifying PCA-ANFIS emotions model based rehabilitation system for rehabilitants easily to use it.
- Investigated the performance of total knee replacement (TKR) rehabilitation by proposed system.
- Investigated the Self-efficacy and System usability influences effectiveness of rehabilitation, and PRS acceptance by rehabilitants.

Knees are the largest joint in the human body. With healthy knees, people can perform most everyday activities like walking and running. Knees are made up of the lower end of the thigh bone (femur), the upper end of the shin bone (tibia), and the kneecap (patella). The ends, or joining points, of these three bones are covered with articular cartilage, a smooth substance that protects bones and enables them to move easily (AAOS, 2011).

Osteoarthritis is one of the ten most disabling diseases in developed countries (WHO, 2010b). For example, there are around 20,000 patients requiring a TKR in Taiwan every year (Bureau of National Health Insurance, 2012), and the rate of hip and knee replacement has increased over the past ten years in many European countries. In Denmark, the hip replacement rate increased by 40% between 2000 and 2010, while the knee replacement rate more than tripled (OECD, 2012). After a TKR, patients require a monotonous and long-term physical rehabilitation process in order to restore the knee's ability. Patients need to endure the pain of the rehabilitation process, and most patients feel discomfort while undergoing the process. Several researchers have started to inquire about ways to improve a patient's rehabilitation achievement.

In the field of rehabilitation, many psychological theories have been utilized to improve patients' rehabilitation motivation; the self-efficacy theory is one. Self-efficacy theory, proposed by Bandura in 1977, is considered one of the most important determinants in the context of total joint replacement (Van den Akker-Scheek et al., 2006). Bandura defined self-efficacy as "the conviction that one can successfully execute the behavior required to produce the desired outcome." Although self-efficacy varied with individuals, patients who had a higher self-efficacy also had a concurrent higher possibility of overcoming obstacles in the rehabilitation process. How to improve the motivation of a person with a lower self-efficacy is an important issue.

In recent years, many therapists have employed virtual reality technologies and motion-based games as intervention tools in rehabilitation. Virtual reality (VR) is defined as "the use of interactive simulations created with computer hardware and software to present users with opportunities to engage in environments that appear to be and feel similar to real world objects and events" (Weiss, Rand, Katz, & Kizony, 2004). VR provides rehabilitants with safe access to interactive and realistic situations that would otherwise be inaccessible to them due to their motor limitations (Rizzo, Buckwalter, & Neumann, 1997; Schultheis & Rizzo, 2001). Moreover, the use of VR can increase motivation for treatment and rehabilitation (Jack et al., 2001). There are two game platforms based on VR, Nintendo Wii Remote/Wii Fit and Microsoft Kinect. In the meantime, Video games are also applied to the field of interactive learning have significant performance effects (Su and Cheng, 2015; Su and Fan, 2014; Fan, Xiao and Su, 2015). Many studies have offered evidence that two such platforms have been useful in rehabilitation (Pasch, 2009;

Chang, 2011; Chao, 2013). In our study, Microsoft Kinect is used, because a controller does not need to be held and no devices need to be installed; the absence of these reduces the patient's burden of control, while performing specified actions. Actors on the screen present a corresponding reaction, allowing patients to have more interaction, thereby increasing their senses of participation and entertainment. Also, the construction cost of Kinect is less than Wii.

This study develops a physical rehabilitation system (PRS) based on PCA-ANFIS emotion model to help TKR patients perform their rehabilitation exercises. The PRS combines kicking games, and patients need only lift their legs to control the game. The aim of the study is to improve TKR patients' rehabilitation achievement by using a PRS, and to explore whether using games in assisting rehabilitation will make patients present a higher self-efficacy, as well as allowing them to be more receptive to the rehabilitation process. In summary, there are five research objectives: (1) design a PCA-ANFIS emotion model based on a 3D Gesture gamification TKR rehabilitation system; (2) enhance the performance knowledge of TKR rehabilitation by a proposed system; (3) investigate how self-efficacy and system usability influence the effectiveness of rehabilitation, and the level of PRS acceptance by rehabilitants; (4) provide insights into the rehabilitation of TKR for remote home care; and (5) encourage patients to enhance their rehabilitation motivation in order to raise their rehabilitation achievement.

The remainder of this paper is organized, as follows: Section 2 reviews the theoretical foundations and related works; Section 3 presents the research methodology and describes the research framework; Section 4 shows the experimental outcomes and the results of data analysis; and finally, the concluding remarks are drawn, and future work is discussed in Section 5.

LITERATURE REVIEW

To set a cornerstone for understanding this study, some related theoretical perspectives and information, based on an analysis of the literature, are briefly introduced in this section.

The Plutchik emotion model

Many previous studies have indicated that emotional control design had been successfully applied in numerous fields, especially in artificial intelligence emotional design (Fan et al., 2015). Some papers have shown that an emotion model should be considered the dynamic interaction of various emotions. Plutchik (1980) proposed a three-dimensional model to describe the relations among emotion concepts which were analogous to the sections on an emotional wheel. The emotional wheel circle represented the degrees of similarity among the emotions. There are eight sectors included in Plutchik's emotional wheel, indicating that there are eight primary emotion dimensions, defined by the theory arranged, as four pairs of opposites (Figure 1). Some researchers used image reorganization patterns to figure out people's emotions, but few of them were based on emotional theory. Plutchik's emotional wheel, however, is organized into eight basic emotions, while the sentiment to "relative," "adjacent" and "different strength" presents more realistic emotions, with a few expressing part of a secondary emotion. Therefore, this study uses PCA-ANFIS-based emotion model, based on a 3D Gesture gamification to implement Plutchik's emotional model as the standard of artificial emotion (Plutchik 1980).

Game-based rehabilitation

The number of rehabilitation games has risen in recent years, and it has been proven that an interactive video-game-based (IVGB) system increases individual interest in related exercises (Lai et al., 2013). Berthouze, Kim & Patel (2013) found that using body movement as the game controller not only increased the level of engagement, but also changed the way the game was played. The results show that a game controller had a critical role in creating a complete game experience. Using

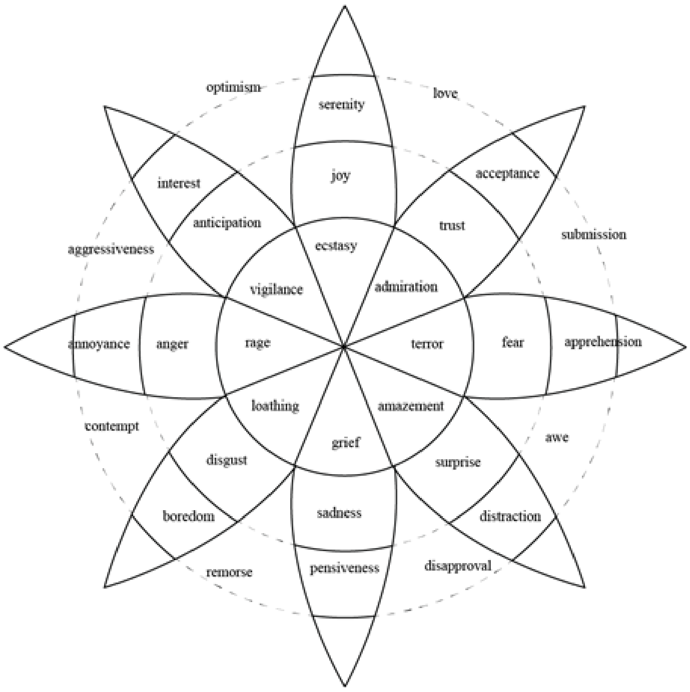


Figure 1. Plutchik emotional Wheel

body movements to control a game allowed players more joy in, and revealed a greater sense of, participation. Therefore, players' motivation to use the system was stronger. O'Connor et al. (2000) attempted to increase the physiological responses of people with spinal cord injury (SCI) and examined the effect of games on their motivation. The results showed that 87% of the participants found that games motivated them to perform their exercises, compared to traditional rehabilitation, in which only 31% of rehabilitants were willing to perform the daily therapist-recommended regime (Shaughnessy, Resnick, & Macko 2006). Accordingly, game-based rehabilitation would increase one's motivation to rehabilitate oneself. It has been employed in many fields of physical rehabilitation, such as that for upper and lower limbs (Chen et al., 2012; Murillo et al., 2003) and burn victims (Parry et al., 2012). These results show the obvious achievement of game-based rehabilitation.

Self-efficacy theory

Self-efficacy theory was proposed by Bandura (Bandura, 1977) and was a key concept in Bandura's social cognitive theory, i.e., someone's confidence in achieving a goal. Higher self-efficacy equates to a higher probability of finishing a task and could reduce anticipatory fears and inhibitions; ergo, self-efficacy can be a decisive factor in determining how one would react when faced with a difficult task (Van den Akker-Scheek et al., 2006). Self-efficacy has two key facets: expectation of result and expectation of self-efficacy (Bandura, 1977).

Expectation of results means that if someone could predict a favorable outcome of his/her behavior, s/he would have stronger motivation to perform the activity.

For example, if a man predicts that exercise would make him healthier, he would be more inclined to exercise. Expectation from self-efficacy means that when someone thinks of performing an activity, and believes that his/her resources can cause expected results, s/he would be more vigorously motivated to perform the activity.

Because self-efficacy performs well in predicting human behavior, it has been employed in many studies, such as chronic disease (Rouhieh et al., 2011), smoking cessation behavior (Chen & Yeh, 2006), and learning behavior (Tsai, Ho, Liang & Lin. 2011). Waldrop, Lightsey, Ethington, Woemmel & Coke (2001) extended Bandura's self-efficacy theory to rehabilitation, and named it self-efficacy for rehabilitation (SER). The 12-item SER was developed following Bandura's guidelines to assess participants' beliefs about their ability to perform activities, typically physical rehabilitation following knee and hip surgeries (Van den Akker-Scheek et al., 2006).

System usability scale (SUS)

Whether a system is accepted or not by users is highly relevant. Without the user's favor, a system must fail, regardless of the attractive interfaces or diverse functionality. A critical factor in system acceptance is system usability.

System usability is defined as "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use" (International Organization for Standardization, 1998). Usability is considered the most important research field in human-computer interaction (HCI). The concept of usability was added to the software industry in 1970 and offered many benefits, for example, increased productivity, customer satisfaction, increased sales and revenues, reduced development time and costs, and decreased training and support costs (Lederer and Prassad, 1992). In 1996, Brooke proposed a system usability scale (SUS) for measuring usability. It was originally created as a "quick and dirty" scale for administering after usability tests on systems like the VT100 Terminal ("Green-Screen") applications. Nowadays, it is an industrial standard with references in over 600 publications (Sauro, 2011). Sauro (2011) improvised grading on a curve for classifying SUS into five ranks from A to F, according to 500 results of a SUS questionnaire (as Figure 2). A PRS able to achieve a ranking higher than B means that the PRS is accepted by most users.

Total knee replacement (TKR)

TKR is a common knee orthopedic surgery. The procedure was developed by Leslie Gordon Percival Shiers (FRCS) in 1954. Following John Charnley's success with hip replacement in the 1960s, attempts were made to design knee

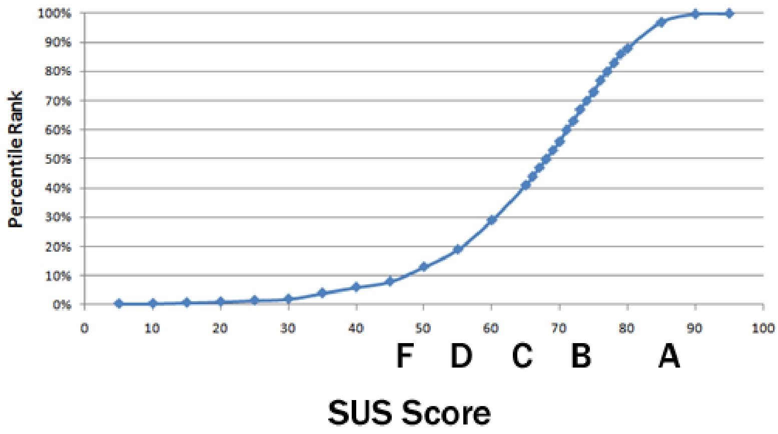


Figure 2. SUS Grading on a curve (Sauro, 2011)

replacements (Ranawat et al., 2012). When a patient's knee is degraded to a point where it causes severe pain or no longer functions, a knee replacement surgery is necessary for patients who suffer from severe osteoarthritis and have impeded mobility. In Taiwan, this surgery costs about $9,000-$10,000 USD; in the United States, it costs $45,000-$60,000 USD (kneereplacementcost.com, 2014). The surgery process utilizes metal and plastic parts to cap the ends of the bones that form the knee joint along with the kneecap.

In Taiwan, healthcare expenditure on TKRs is 2.6 billion NT$, and, due to an aging population, increasing annually. The 65-74-year-old age group accounts for 41.76% of TKR patients; the 75-84 -year-old age group, 35.14%; those between 55-64, 16.27%; over 85 with 4.11%; and under 55 with 2.72%; additionally, 74.55% of patients are women (NHI, 2012). It is inferred that age is a risk factor in the knee's condition. The related literature indicated other risk factors, such as obesity, physical inactivity, smoking and excessive use of alcohol, and previous injuries (European Commission, 2008b).

The success rate of TKRs is about 95%. Most patients are satisfied with their surgeries, and 90% of TKR patients can go 10 years without changing their artificial prosthesis, and 80% of patients go 20 years or more. After a TKR, patients usually stay in the hospital about a week to undergo rehabilitation for reconstructing the knee's ability.

RESEARCH DESIGN AND SYSTEM DEVELOPMENT

This section describes the research design, participants, questionnaire design, developed PRS system, and quasi-experiment.

Research design

This study explores whether using a motion-based 3D game could assist in TKR rehabilitation and raise patient's self-efficacy, to the extent that patients would have stronger motivation towards rehabilitation, enabling a subsequent rapid return to their daily activities after surgery. Much past research was conducted to ascertain the extent to which Nintendo Wii and Wii Fit assisted patients in rehabilitation. Patients needed to hold the remote to control Wii and stand on a balance board. Some patients complained about using these devices. Therefore, Microsoft Kinect was selected as the game control tool for this study. Patients need only perform some appropriate activities to interact with the screen actor, and can enjoy the game without having to hold any devices.

For evaluating the achievement of the developed PRS, this study conducted a quasi-experiment. The design includes post-test and randomly assigns rehabilitants into two groups, experimental and control. The experimental group implements the developed PRS system for assisting in rehabilitation.

Operational definitions

This section defines research variables in terms of the specific operations that measure them in particular ways. These variables include a dependent variable of rehabilitation achievement and independent demographic variables, self-efficacy, and system usability. The definitions of variables and the cited reference are listed in Table 1.

Hypotheses

Based on the above studies (Bandura, 1977., Beckwée et al., 2013., Dauty et al., 2009., Kubeck et al., 1996., Sallis et al., 1988 & Vincent et al., 2006) with demographic variables, this study considers the relationship between demographic

Table 1. Operational definition

Variable	
Rehabilitation Achievement	The rehabilitation achievement is evaluated by the American Knee Society Score (AKSS, Medalla et al., 2008). AKSS is the most widely used physician-assessed measure of knee functionality after a TKR. The domains cover pain, function, absence of deformity, and range of motion.
Demographic variable: Gender	There are gender differences in information technology use and implementation (Reinen & Plomp, 1997). Gender differences will produce different results in rehabilitation (Vincent et al., 2006).
Demographic variable: Age	Age is related to the achievement of computer-based tasks. In general, older adults are slower and commit more errors in training tasks (Kubeck, Delp, Haslett & McDaniel, 1996). Older adults have a slower recovery than younger people (Vincent et al., 2006).
Demographic variable: Experience	Participants' experiences in using similar gaming systems. Experience will affect a user's self-efficacy (Bandura, 1977).
Demographic variable: Exercise Habit	Exercise habits will affect a person's confidence (Sallis et al., 1988). Someone who is used to exercising will have better physical functionality (Mirowsky & Ross, 2003). Exercise habits may result in better cartilage metabolism for better rehabilitation (Beckwée et al., 2013).
Demographic variable: Health State	Mentation will affect self-efficacy (Bandura, 1977). Dauty et al. (2009) said that previous arthroplasty would affect a rehabilitant's recovery status.
Self-efficacy	Holden & Rada (2011) said that both self-efficacy and perceived usability had a positive correlation in education. Self-efficacy is considered one of the more important determinants in the context of total joint replacement (Van den Akker-Scheek et al., 2006).
System Usability	Usability is not a quality that exists in any real or absolute sense (Brooke, 1996).

variables and system usability, as well as self-efficacy and rehabilitation achievement. Three hypotheses are proposed, as follows:

H1: A rehabilitant's demographic variables will affect the rehabilitation self-efficacy.

H1a: A rehabilitant's exercise habits will affect the rehabilitation self-efficacy.

H1b: A rehabilitant's prior knee-related diseases will affect the rehabilitation self-efficacy.

H1c: A rehabilitant's gender will affect the rehabilitation self-efficacy.

H1d: A rehabilitant's age will affect the rehabilitation self-efficacy.

H1e: A rehabilitant's use experience with motion capture tools will affect the rehabilitation self-efficacy.

H2: A rehabilitant's demographic variables will affect the perceptions of system usability.

H2a: A rehabilitant's exercise habits will affect the perceptions of system usability.

H2b: A rehabilitant's prior knee-related diseases will affect the perceptions of system usability.

H2c: A rehabilitant's gender will affect the perceptions of system usability.

H2d: A rehabilitant's age will affect the perceptions of system usability.

H2e: A rehabilitant's use experience with motion capture tools will affect the perceptions of system usability.

H3: A rehabilitant's demographic variables will affect the rehabilitation achievement.

H3a: A rehabilitant's exercise habits will affect the rehabilitation achievement.

H3b: A rehabilitant's prior knee-related diseases will affect the rehabilitation achievement.

H3c: A rehabilitant's gender will affect the rehabilitation achievement.

H3d: A rehabilitant's age will affect the rehabilitation achievement.

H3e: A rehabilitant's use experience with motion capture tools will affect the rehabilitation achievement.

Holden & Rada (2011) explored self-efficacy and perceived that usability had a positive correlation in the education field. This study intends to explore whether the results are consistent with their study in rehabilitation. Bentsen et al. (2010) found that with higher self-efficacy, COPD (chronic obstructive pulmonary disease) patients had a better PR (pulmonary rehabilitation) program outcome. Likewise, this study proposes to test whether this would be the same as the TKR rehabilitation achievement. There is no relative study on the relationship between the perceptions of system usability and rehabilitation achievement, but physicians suggest exploring this possibility. According to the above related works, this study submits the following hypotheses to explore the relationships of system usability, self-efficacy and rehabilitation achievement:

H4: That self-efficacy and the system usability have a relationship.

H5: That self-efficacy will affect the rehabilitation achievement.

H6: That differing perceptions of system usability will result in different rehabilitation achievements.

The relationship of the six hypotheses constitutes the research framework of this study, as shown in Figure 3.

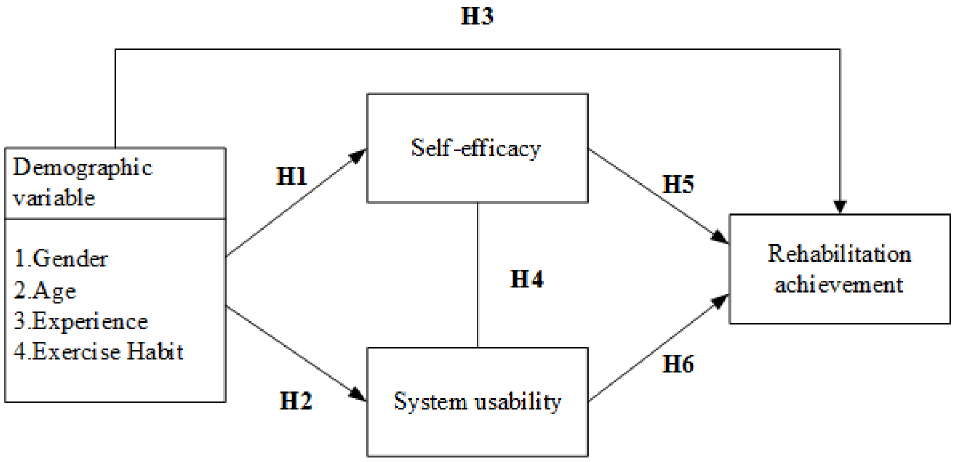


Figure 3. Research framework

PARTICIPANTS AND QUESTIONNAIRE DESIGN

This section describes the selection of participants and the questionnaire design employed to evaluate user self-efficacy and rehabilitation achievement.

Participants

The developed PRS is designed for rehabilitant implementation two days after a TKR, when the patient can get out of bed and perform slight active ROM exercises without assistance and only minimal pain. This study was performed in cooperation with a regional hospital in Kaohsiung, Taiwan, and chose 34 rehabilitants who fit the above criteria.

Table 2. SER Questionnaire (Waldrop et al., 2001)

SER items (range 0-10)	**During my rehabilitation, I believed I could do**
1.	therapy that required me to stretch my leg.
2.	therapy that required me to lift my leg.
3.	therapy that required me to bend my leg.
4.	therapy that required me to stand.
5.	therapy that required me to work.
6.	all of my therapy exercises.
7.	my therapy every day it was scheduled.
8.	the exercises prescribed by my therapists, even if I didn't understand how they would help me.
9.	my therapy no matter how I felt emotionally.
10.	my therapy no matter how tired I felt.
11.	my therapy, even though I may have had other illness complications.
12.	my therapy regardless of the amount of pain I was feeling.

Table 3. American Knee Society score example (orthopaedicscores.com, 2014)

Part 1 – Knee score	
Pain	**Flexion Contracture (if present)**
None(50)	<5°(0)
Mild / Occasional)(45)	5°-10°(-2)
Mild (Stairs only)(40)	11°-15°(-5)
Mild (Walking and Stairs(30)	16°-20°(-10)
Moderate – Occasional(20)	>20°(-15)
Moderate – Continual(10)	
Severe(0)	
Extension lag	**Alignment (Varus & Valgus)**
<10°(-5)	0°(-15) , 1°(-12) , 2°(-9) , 3°(-6) ,4°(-3)
10°-20°(-10)	5°-10° (0)
>20°(-15)	11° (-3), 12° (-6) , 13° (-9) , 14°(-12) , 15° (-15)
	Over 15°(-20)
Total Range of Flexion	
_____ (5º = 1 point, with a 25-point maximum, and a possible range of 0 º to 125 º)	
Part 2 - Function	
Walking	**Stairs**
Unlimited (50)	Normal up and down (50)
>10 blocks (40)	Normal up down with rail(40)
5-10 blocks (30)	Up and down with rail (30)
<5 blocks (20)	Up with rail, down unable (15)
Housebound (10)	Unable (0)
Unable (0)	
Walking aids used	
None used (0)	
Use of cane/walking stick deduct (-5)	
Two canes/sticks (-10)	
Crutches or frame (-20)	

The 34 participants were assigned to one of two groups: one group of 18 rehabilitants was the experimental group; the other, of 16 rehabilitants, was the control group. All rehabilitants were treated by the same physical therapist. The participants in the experimental group used traditional rehabilitation with a PRS. The rehabilitants in the control group used the traditional rehabilitation approach without any aid devices.

Questionnaire design

SER scale

To evaluate self-efficacy, the SER scale refers to the study of Waldrop et al. (2001) as the questionnaire (see Table 2). The SER scale, which has 12 items and uses an 11-point Likert scale, from 0 (I cannot) to 10 (I can), was developed

Table 4. Demographic variables

Variable	Statement	Data pattern
Gender	Denote the rehabilitant gender: male or female.	Nominal
Age	Denote the rehabilitant age.	Numeric
Experience in using motion capture tools	Have you ever used motion capture tools: Yes or No.	Nominal
Exercise habits	Do you exercise daily: Yes or No.	Nominal
Related diseases	Have you had any previous knee-related diseases: Yes or No.	Nominal

Table 5. System usability scale (Brooke, 1996)

Questionnaire Item	Strongly disagree	Strongly disagree
1. I think that I would like to use this system frequently.	1	5
2. I found the system unnecessarily complex.	1	5
3. I thought the system was easy to use.	1	5
4. I think that I would need the support of a technician to be able to use this system.	1	5
5. I found the various functions of this system were well integrated.	1	5
6. I thought there was too much inconsistency in this system.	1	5
7. I would imagine that most people would learn to use this system very quickly.	1	5
8. I found the system very cumbersome to use.	1	5
9. I felt very confident using the system.	1	5
10. I needed to learn a lot of things before I could use this system.	1	5

following Bandura's guidelines to assess participants' belief in their ability to perform certain actions, typically, physical rehabilitation, following a knee or hip surgery. A Cranbach alpha of 0.94 shows that patients could finish the questionnaire by themselves.

Typical items include "During my rehabilitation, I believed I could do therapy that required me to stretch my leg," and "I believed I could do my therapy regardless of the amount of pain I was experiencing" (Stevens et al., 2005).

AKSS scale

For evaluating the rehabilitation achievement, this study uses the AKSS to evaluate the knee condition by patient and clinician. The AKSS and the Oxford knee score (OKS) are commonly used in the United Kingdom (Medalla et al., 2008). This research chooses the AKSS as the questionnaire to measure knee conditions, because the AKSS considers the ROM angle for evaluation, which the OKS does not, meaning that AKSS has more objective standards by which to judge a patient's knee condition.

The AKSS consists of a knee score and a function score (as Table 3). The knee score assesses pain, stability and ROM, and the function score assesses situational walking conditions, stair climbing, and use of walking aids. In coordination with hospitals, physicians suggest "anteroposterior" and "mediolateral" items for the knee score questionnaire. This study removes the discussion of the knee score, because a function score depends on a patient's feelings and would be subjective.

Demographic scale

This study uses gender, age, use experience in motion capture tools, exercise habits, and related diseases as the demographic variables for exploring the demographic relationship with self-efficacy and system usability. Table 4 describes the demographic variables.

SUS scale

SUS scales are used for evaluating the PRS system usability. When the PRS reaches a rank higher than B (score >70), the PRS is acceptable by most users.

The SUS is a simple questionnaire using 5-Likert scales to assess software usability. It was developed by John Brooke at Digital Equipment Corporation in the

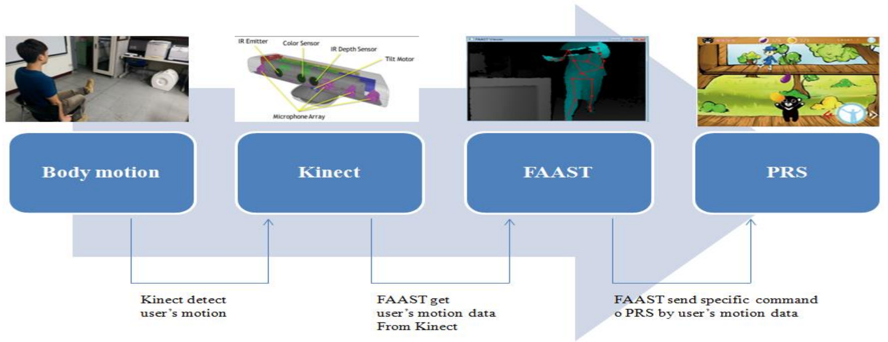


Figure 4. System architecture

Table 6. System development process

1.Analyze
Select suitable system solution • Develop tool (Unity3D or other game software). • Program language (C sharp / JavaScript). • SDK for control Kinect (OpenNI / Kinect for Windows SDK). • How to combine Unity3D and Kinect (Kinect for Unity3D Plugin / FAAST).
2.Design
• How to control the PRS (with which body movement(s)). • Interface of the PRS (the screen). • Design the system process of the PRS.
3.Develop / Implement
• Start to develop a PRS with a selected tool, program language and SDK.
4.Testing and fixing
• Recruit volunteers to test PRS usability. • Fix bugs.

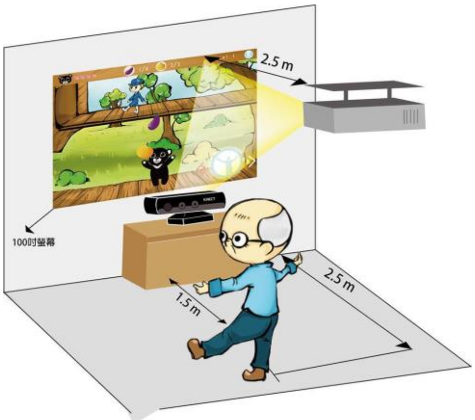


Figure 5. Environment setting

UK (Brook, 1996). There are 10 items in the SUS scale (as Table 5). The scoring of SUS is introduced, as follows:

- For odd-numbered items: subtract one from the user response.
- For even-numbered items: subtract the user response from 5.
- This scale's values are from 0 to 4 (with four being the most positive response).
- Add the converted responses for each user and multiply the total by 2.5. This converts the range of possible values from 0 to 100, instead of from 0 to 40.

System development

For developing the PRS, this study uses a Unity 3D as the developing tool. Unity 3D is a game developing tool which has been widely used in the game industry. It can develop games rapidly on a computer and a mobile device, and uses Flexible Action and Articulated Skeleton Toolkit (FAAST) as the middleware, so that users can interact with the PRS by Kinect.

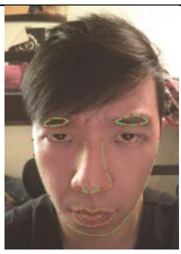
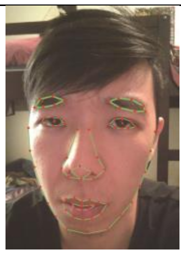
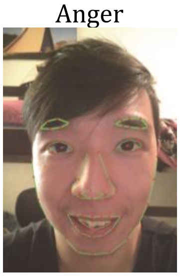
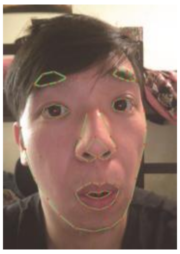
The system was developed by the prototype method. A PRS prototype was first developed and revisions discussed with game experts and physicians, so as to better fit the needs of this study. Table 6 describes the system development process in detail, and Figure 4 shows the system architecture, explaining the software and hardware used and how they work together.

System environment setting

Rehabilitants stand or sit on chairs. The Kinect sensor is set on or near a computer monitor in front of rehabilitants to capture their body movements. In order to capture completely the rehabilitant's movements, the rehabilitant's distance from the monitor is 2~6 feet. Rehabilitants don't need to wear any assistance devices; the PRS is controlled by lifting their legs. The environment setting is shown as Figure 5.

The PRS starts when the Kinect sensor is connected to the computer. It detects

Table 7. Facial emotion model

		
Anger	Disgust	Fear
		
Joy	Sadness	Surprise

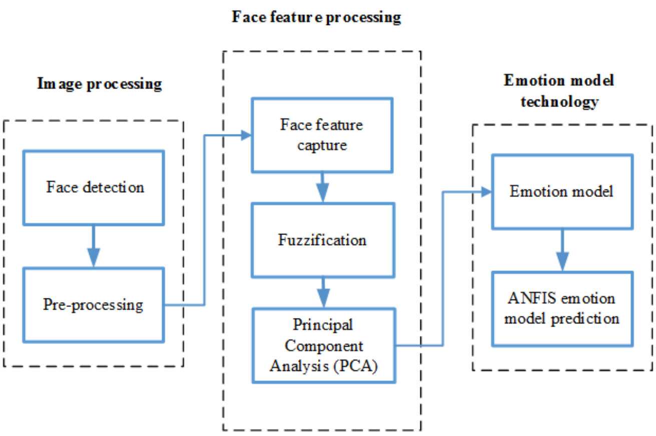


Figure 6. PCA-ANFIS emotion model recognition flow

the rehabilitant's skeletal points, and the rehabilitant need only make a slight bodily movement for the Kinect sensor to capture the skeletal point. After the detection, the PRS continues the rehabilitation process.

PRS with PCA-ANFIS based emotions model gesturing process

A lot of researchers used to study and develop "facial expression recognition" in the research on Kansei Engineering, where Ekman & Friesen (1971) defined six basic facial expressions about the muscle distribution on the face, including Anger, Disgust, Fear, Joy (Happy), Sadness, and Surprise, Table 7.

In traditional expression recognition systems, a lot of people's face information is required for establishing a common expression model to judge the user's expression (Bae & Kim, 2005; Xie & Lam, 2008). However, everyone has the facial feature location and shows different expression degrees and methods that misjudgment is likely occurred. Nevertheless, the accuracy could be effectively enhanced when an emotion model is used as the recognition criteria and a user's personal information is applied to judge the expression. The advantages of facial feature location changes and facial image statistics therefore are utilized and combined with the emotion model as the reference of judgment to propose an emotion model based facial expression recognition in this study. PCA-ANFIS emotion model recognition flow is explained as figure 6.

1. Image processing: containing face detection technology and pre-processing

(1) Face detection: Capturing facial images from original images.

(2) Pre-processing: The captured facial images are processed before expression recognition and face recognition.

2. Face feature processing:

(1) Face feature capture: Capturing face features from facial images.

(2) Fuzzification: The coordinate of face features captured from facial images is fuzzified.

(3) Principal Component Analysis (PCA): Principal Component Analysis (PCA) is

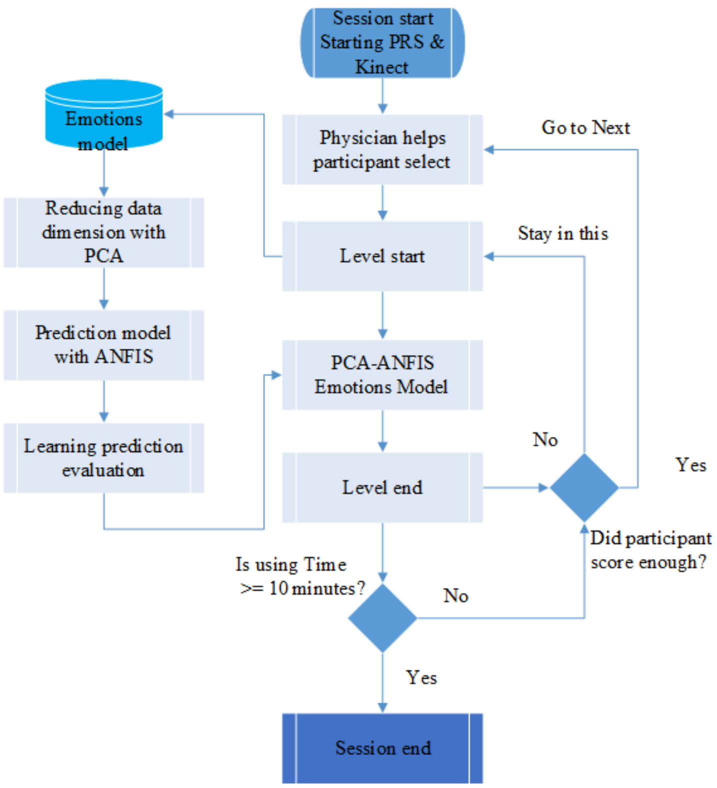


Figure 7. The process of PCA-ANFIS emotions gesturing model

preceded after fuzzifying the coordinate of face features.

3. Emotion model technology: The user's expression is judged by captured face features and the face recognition result.

(1) Emotion model: The emotion model is regarded as the reference of the recognition criteria model.

(2) ANFIS (adaptive neuro-fuzzy inference system): The ANFIS emotion model prediction is preceded.

Before participants start the exercise in each section, they have a 10-minute massage by the physical therapist and 10 minutes of electrotherapy. During the PRS rehabilitation period, the participants in the experimental group perform a keen flexion action without wearing any aid devices, while the Kinect sensor captures the rehabilitant's motion to control the game. When the participants kick their feet, the actors in the game raise their feet to kick the fruit on the screen, and the actors to left or right are moved by raising their left or right arm. This game gives a score at the end, which reflects the gaming performance of the participant. When a rehabilitant accrues a sufficient game score, s/he can advance to the next game level, the level of the PRS affecting the difficulty of the game, with more and faster fruit dropping. Figure 7 shows the process of using the PRS. Participants with higher scores suggest more advanced states of recovery. The PRS use time depends on the rehabilitant's state of recovery. Rehabilitants in the control group only do routine physical rehabilitation, without any aid devices. When participants perform active ROM exercises, the physical therapist offers the necessary guidance, mindful of the rehabilitant's recovery state, and makes sure no accidents occur in the experiment period. The process of PCA-ANFIS emotion gesturing model is implemented in three steps. The details of this process are described (see Figure 7), as follows: Step 1 Setting Model, for reducing data dimension with PCA; Step 2 Modeling, for establishing the prediction model with ANFIS; and Step 3 Learning Prediction Evaluation, for the evaluation of prediction capability.

Step 1 Setting model, for reducing data dimension with PCA

The principal components analysis (PCA), a popular statistical tool, is used for reducing the dimensionality of a set of variables (often called features), while retaining the maximum variability (minimum loss of information) in terms of the variance–covariance structure (Jolliffe, 2002). The high dimensional data space is also analyzed by using a multivariate statistical learning tool, i.e., the principal component analysis (PCA). An effort is made to describe the evolved principal components, as the newly extracted features, and to correlate them with the characteristics of Plutchik's emotion model data set. In other words, the PCA explains the variance–covariance structure of a data set, using a new set of coordinate systems, known as principal components, which is lesser in dimension than the number of the original variables. The PCA algorithm's five steps are performed, as below.

(i). The standardization of the original indicator data collects n samples $\mathrm{x_i} = (\mathrm{x_{i1}}, \mathrm{x_{i2}}, \ldots, \mathrm{x_{ip}})^{\mathrm{T}}$, i = 1,2,...,n, from the random vector $x = (x_1, X_2, \ldots, X_p)^T$) in p dimension,

n＞p. The structural sample matrix is preceded by a standardization transformation of the sample matrix elements.

$$Z_{ij} = \frac{x_{ij} - x_j}{s_j}, i = 1,2, \ldots, n; j = 1,2, \ldots, p \qquad (3.1)$$

where $x_j = \frac{\sum_i^n = 1\, X_{ij}}{n}$, $s_j^2 = \frac{\sum_i^n = 1\, (X_{ij} - X_j)^2}{n-1}$ to acquire the standardized matrix Z.

(ii). Calculate correlation coefficient matrix on the standardized matrix Z.

$$R = [r_{ij}]_p\, xp = \frac{Z^T Z}{n-1} \qquad (3.2)$$

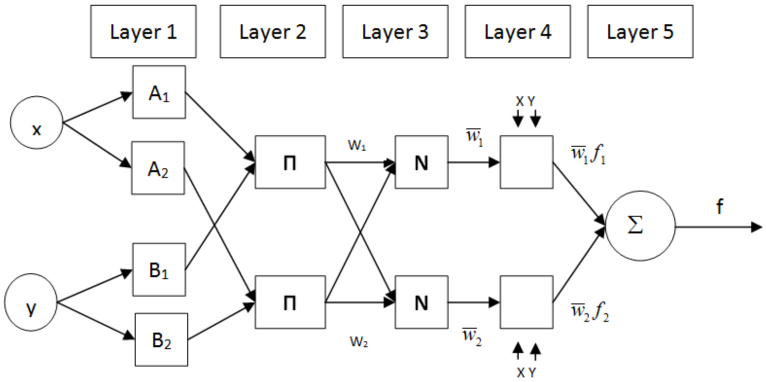


Figure 8. The architecture of an ANFIS network

where $r_{ij} = \frac{\sum z_{kj} \cdot z_{kj}}{n-1}, i, j = 1,2, \ldots, p.$ (3.3)

(iii). Solve the characteristic equation $|R - \lambda I_P| = 0$ of the sample correlation matrix R to acquire p characteristic roots and confirm the principal component.

Confirm m with $\frac{\sum_{j=1}^{m} \lambda_j}{\sum_{j=1}^{p} \lambda_j} \geq 0.85$ to make the information use rate reach above 85%. Solve the equation $Rb = \lambda_j b$ with each λ_j, j = 1,2,...,m to acquire the unit eigenvector b_j^o.

(iv). Transform the standardized indicator variables into principal component.

$U_{ij} = z_i^T \, b_j^o, j = 1,2, \ldots, m$ (3.4)

U_1 is the first principal component, U_2 is the second principal component…, and U_p is the p-th principal component.

(v). Comprehensively evaluate m principal components.

m principal components are weighted and summed for the final evaluation value. The weight is the variance contribution rate of each principal component.

Step 2 Modeling, for establishing the prediction model with ANFIS

ANFIS (Jang 1993) integrates the best features in fuzzy systems (FS) and neural networks (NN). ANFIS has been employed with different applications, such as controllers (automated fuzzy control tuning) and models (to explain past data and predict future behaviors). To illustrate the system, a fuzzy inference system, consisting of five layers of adaptive network with two inputs, *x* and *y*, and one output, *z*, is assumed. The architecture of ANFIS is shown as Figure 8.

Then, supposing that the system consists of 2 fuzzy if-then rules, based on Takagi and Sugeno's type (Takagi and Sugeno 1983),

Rule 1: If x is A_1 and y is B_1, then $f_1 = p_1 x + q_1 y + r_1$

Rule 2: If x is A_2 and y is B_2, then $f_2 = p_2 x + q_2 y + r_2$.

The node in the *i-th* position of the *k-th* layer is denoted as $O_{k,i}$, and the node functions in the same layer are of the same function family, described below.

Layer 1: This is the input layer, and every node *i* in this layer is a square node with a node function (see Equation (3.5)). $O_{1,i}$ is the membership function of A_i and specifies the degree to which the given x satisfies the quantifier A_i. Usually, the bell-shaped membership function is selected as the input membership function (see Equation (3.6)) with the maximum equal to 1 and the minimum equal to 0.

$O_{1,i} = \mu A_i(x)$ for *i*=1, 2 (3.5)

$$\mu A_i(x) = \frac{1}{1+[(\frac{x-c_i}{a_i})^2]^{bi}} \quad (3.6)$$

where a_i, b_i, c_i are the parameters, b is a positive value and c denotes the center of the curve.

Layer 2: Every node in this layer is a square node labeled Π which multiplies the incoming signals and sends the product out by Equation (3.7).

$$O_{2,i} = w_i = \mu A_i(x) \times \mu B_i(y) \text{ for } i=1, 2 \quad (3.7)$$

Layer 3: Every node in this layer is a square node labeled N. The *i-th* node calculates the ratio of the *i-th* rule's firing strength to the sum of all rules' firing strengths by Equation (3.8). Output of this layer can be called normalized firing strengths.

$$O_{3,i} = \overline{w}_i = \frac{w_i}{w_1 + w_2} \quad \text{for } i=1, 2 \quad (3.8)$$

Layer 4: Every node i in this layer is a square node with a node function (see Equation (3.9). Parameters in this layer are referred as consequent parameters.

$$O_{4,i} = \overline{w}_i f_i = \overline{w}_i(p_i x + q_i y + r_i) \quad (3.9)$$

where p_i, q_i, r_i are the parameters.

Layer 5: The single node in this layer is a circle node labeled $\sum$ that computes the overall output as the summation of all incoming signals (see Equation (3.10))

$$O_{5,i} = \sum_i \overline{w}_i f_i = \frac{\sum_{i=1} w_i f}{\sum_{i=1} w_i} = \text{overall output} \quad (3.10)$$

Step 3 Learning prediction evaluation, for the evaluation of prediction capability.

After ANFIS training, the preliminary inference system presents training data, which are further applied to acquire the preliminary results. Training data of two cases are analyzed for verifying the accuracy of the prediction model. Both ANFIS and regression analyses are applied to establish the prediction model and verify the accuracy. ANFIS, after PCA classification, deals with data training and testing with the predictions of SVR and regression analysis. Finally, the optimal model is selected for evaluating the prediction capability. The commonly used regression analysis for predictions is further compared to explain the practicability of ANFIS.

Experiment procedure

This study was performed in cooperation with a regional hospital in Kaohsiung, Taiwan. The experiment procedure is shown in Figure 9. Initially, the rehabilitants were randomly assigned to either the experimental or control group; subsequently, their demographic variables and SER were investigated, and the week-long rehabilitation process began. The experimental group took the traditional 30-minute rehabilitation session and used a PRS for 10 minutes, while the control group only took the 30-minute session. SER is self-reported so rehabilitants can finish it by themselves, but AKSS testing needs a physician's assistance. A total of 34 TKR rehabilitants took part in the experiment; the experimental group applies rehabilitation activities and uses a PRS, while the control group utilizes only rehabilitation activities. Both groups use the same procedure with the same activities and content. For both groups, rehabilitation is preceded by the same rehabilitation activities pre-test (X1, X3) and both the AKSS and the SUS results post-test (X2, X4). Figure 9 shows the experiment process and the time allotments for each section.

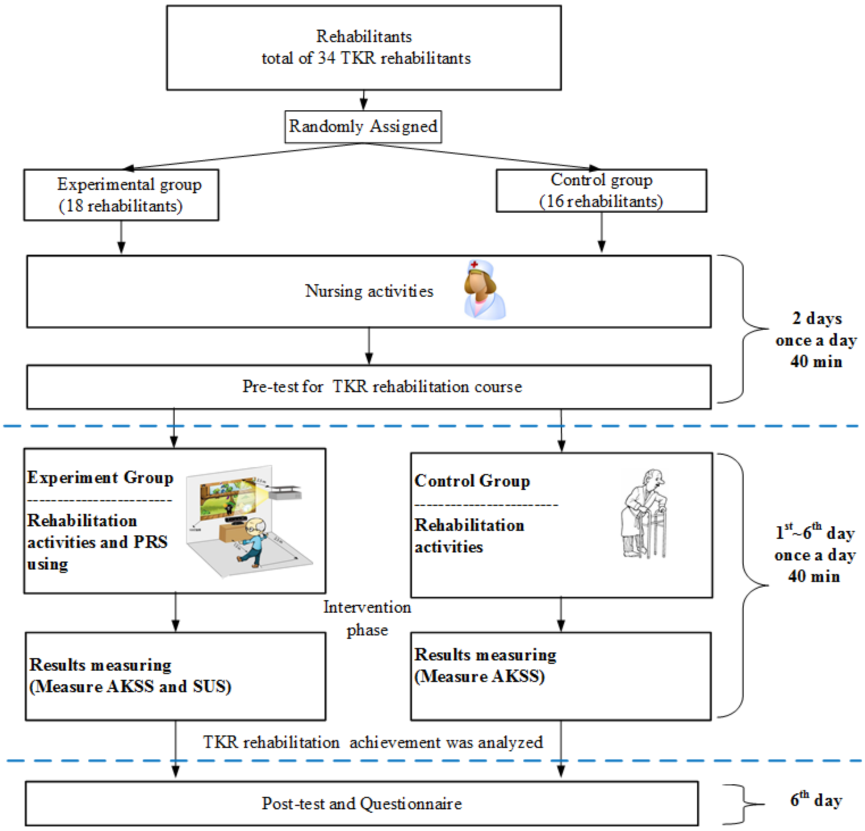


Figure 9. Experiment procedure

RESULTS AND FINDINGS

In this study, TKR rehabilitants' self-efficacy is measured and the effect of different strategies (group) on rehabilitation achievement is analyzed. A total of 34 TKR rehabilitants participated in this study, of which 18 are in the experimental group and 16 in the control group. The full model of hypothesized relationships is statistically tested by using an SPSS software package, and the significance level is set as $p \leq 0.05$ for the statistics. In descriptive statistics, the frequencies, means and standard deviations are calculated by the subject's responses to the questionnaire. The differences between the experimental group and the control group in the SER and AKSS are analyzed by using an independent samples t-test, to explore the differences of the experimental group's self-efficacy, system usability and rehabilitation achievements. The Mann-Whitney U test is used for small samples. Nonparametric statistics contains the advantages of being able to apply to variables in nominal or ordinal scale measurements and small-sample tests not corresponding to normal distribution (Siegel and Castellan, 1988; Vargha and Delaney, 2000). To investigate the relations between rehabilitants' self-efficacy and system usability, correlation analysis is used.

Table 8. Descriptive statistics result

Item	Control group Mean(SD)	Experiment group Mean(SD)
Number of participant	16	18
Age	68.56(2.897)	65.88 (4.296)
Gender	Female：9	Female：9
	Male：7	Male：9
Experience in using motion capture tools	Yes：6	Yes：9
	No：10	No：9
Exercise habits	Yes：8	Yes：11
	No：8	No：7
Knee-related diseases	Yes：8	Yes：8
	No：8	No：10
SUS average		77.91(14.55)

Table 9. Descriptive statistics and independent samples Mann-Whitney U test

Factor	Group	N	Mean	SD	U test for same distribution		
					Standardized test statistic	Sig. (2-Tailed)	Comparison
Self-efficacy	Female	9	83.111	15.045	-2.352	.019	M > F
	Male	9	103.444	7.178			
	Age ≤ 65	7	106.571	1.902	-3.186	.000	Y > O
	Age > 65	11	84.818	14.274			
	Inexperienced	9	80.556	11.918	-3.240	.000	E > I
	Experienced	9	106.000	2.062			
	No habit	7	76.286	13.951	-3.414	.000	H > NH
	With habit	11	104.091	. 6.595			
	No disease	10	104.200	6.941	-3.349	.000	D > ND
	With disease	8	79.625	11.747			
System usability	Female	9	69.444	15.701	-2.711	.006	M > F
	Male	9	86.388	6.508			
	Age ≤ 65	7	89.642	5.289	-3.191	.000	Y > O
	Age > 65	11	70.454	13.639			
	Inexperienced	9	67.778	13.718	-3.378	.000	E > I
	Experienced	9	88.056	5.559			
	No habit	7	64.643	7.544	-3.282	.000	H > NH
	With habit	11	86.364	6.458			
	No disease	10	85.500	6.101	-2..460	.012	D > ND
	With disease	8	68.438	16.794			

Note. M = Male; F = Female; Y = Younger group (age ≤ 65); O = Older group (age > 65); E = Experienced in using commercial motion-capture tools; I = Inexperienced in using commercial motion-capture tools; H = Had daily exercise habit; NH = Had no daily exercise habit. D = Had previous knee-related disease; ND = Had no previous knee-related disease.

Collected data and description statistics

Three questionnaires are designed for measuring basic participant information. The SUS questionnaire only measures the experimental group for testing the developed PRS usability, and the SER is employed to evaluate the confidence in finishing the rehabilitation process. Table 8 shows the descriptive statistics result. Of the 18 participants in the experimental group, 9 are male and 9 female (mean age = 65.88, *SD* = 4.296). Nine participants (50%) have experience in using motion capture tools; 11 participants (61%) have daily exercise habits; and 8 participants (44%) have had previous knee-related diseases. In the control group, there are 16 participants, 7 males and 9 females (mean age = 68.56, *SD* = 2.897). In system usability, the participants in the experimental group got an average score 77.91 (*SD* = 14.55) in the SUS, showing that the PRS is acceptable.

Results of hypotheses

For testing hypotheses H1 and H2, the Mann-Whitney U test is performed to test the statistically significant disparities in self-efficacy and perceptions of PRS usability among rehabilitants with different demographic variables. From Table 9, the results show that all demographic variables (gender, age, experience in using a similar system, exercise habit and previous knee-related diseases) have significant differences in self-efficacy ($p<.05$) and system usability ($p<.05$). The results support hypotheses H1 and H2, indicating that these demographic variables will affect the confidence in finishing the rehabilitation process and the efficiency of learning a new system.

Table 10. Descriptive statistics and independent samples t-test for the difference of demographic variables in rehabilitants' rehabilitation achievements

Factor	Group	N	Mean	SD	t-test for Equality of Means			
					T-Value	df	Sig. (2-Tailed)	Comparison
Knee score	Female	18	40.83	15.459	-3.979	32	.000	M > F
	Male	16	61.25	14.318				
	Age ≤ 65	8	71.25	12.174	4.859	32	.000	Y > O
	Age > 65	26	44.04	2.801				
	Inexperience	19	38.68	12.343	-6.356	32	.000	E > I
	Experienced	15	65.33	11.872				
	No habit	15	36.00	10.724	-6.128	31.995	.000	H > NH
	With habit	19	61.84	13.865				
	No disease	18	60.83	13.531	4.497	32	.000	ND > D
	With disease	16	38.75	15.111				
Function score	Female	18	36.44	7.262	-1.843	32	.075	
	Male	16	41.63	9.113				
	Age ≤ 65	8	48.63	3.701	4.805	32	.000	Y > O
	Age > 65	26	35.88	7.157				
	Inexperience	19	34.42	6.628	-4.259	32	.000	E > I
	Experienced	15	44.56	7.180				
	No habit	15	33.67	3.266	-3.775	32	.000	H > NH
	With habit	19	43.00	9.098				
	No disease	18	42.83	9.332	3.412	24.843	.002	ND > D
	With disease	16	34.44	4.412				

Note. M = Male; F = Female; Y = Younger group (age ≤ 65); O = Older group (age > 65); E = Experienced in using commercial motion-capture tools; I = Inexperienced in using commercial motion-capture tools; H = Had daily exercise habit; NH = Had no daily exercise habit. D = Had previous knee-related disease; ND = Had no previous knee-related disease.

Table 11. Descriptive statistics and Mann-Whitney U test for the difference of rehabilitation performances in rehabilitants' self-efficacy and perceptions of PRS usability, divided by the median

Factor	Group	N	Mean	SD	U test for same distribution		
					Standardized test statistic	Sig. (2-Tailed)	Comparison
Self efficacy	knee score ≥ 45	9	103.44	7.126	-2.441	.014	H > L
	knee score < 45	9	83.11	15.070			
	function score ≥ 57.5	9	104.11	4.859	-2.352	.019	H > L
	function score < 57.5	9	82.44	14.926			
System usability	knee score ≥ 45	9	86.11	6.744	-2.489	.011	H > L
	knee score < 45	9	69.72	15.932			
	function score ≥ 57.5	9	86.39	6.509	-2.711	.006	H > L
	function score < 57.5	9	69.44	15.701			

*Note. H = High-performance (*knee score ≥ 45, function score ≥ 57.5*); L = Low-performance (*knee score < 45, function score < 57.5*)*

For testing hypothesis H3, an independent samples t-test is performed to examine the statistically significant disparities in the rehabilitation achievements of the knee score and the function score among different demographic variables. The results in Table 10 show that the knee scores appear different, based on demographic variables (p<.05), and that the function score has a demographic variable difference (p<.05).

Table 12. Regression analysis for self-efficacy on rehabilitation and rehabilitation performances

Dependent Variable	Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
Knee score	(Constant)	7.042	4.827		1.459	.154
	SER Q7	4.348	.646	.765	6.728	.000
Function score	(Constant)	-5.282	5.806		-.910	.370
	SER Q8	8.166	.820	.869	9.958	.000

Table 13. Regression analysis for PRS usability on rehabilitation and rehabilitation performances

Dependent Variable	Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
Knee score	(Constant)	18.037	3.215		5.610	.000
	SUS Q1	4.444	1.771	.498	2.510	.024
	SUS Q9	3.222	1.446	.442	2.229	.042
Function score	(Constant)	-28.892	13.900		-2.079	.055
	SUS Q1	15.630	3.616	.621	4.323	.001
	SUS Q8	11.860	4.296	.397	2.761	.015

Table 14. Analysis of different rehabilitation conditions on rehabilitation achievement (Knee Score, Knee function) and Self-efficacy

Factor	Group	N	Mean	SD	t-test for Equality of Means			
					T-Value	df	Sig.	Comparison
Knee score	Experimental group	18	42.11	7.498	-2.545	32	.016	E > C
	Control group	16	35.25	8.226				
Function score	Experimental group	18	55.56	21.136	-1.879	27.165	.071	
	Control group	16	44.49	11.757				
Self efficacy	Experimental group	18	93.28	15.499	-2.264	32	.030	E > C
	Control group	16	82.13	12.889				

Note. E = Experimental group; C = Control group. Confidence interval percentage: 95

Table 15. The result of hypotheses

Hypothesis		Result
$H1_a$	A rehabilitant's exercise habits will affect the rehabilitation self-efficacy.	Supported
$H1_b$	A rehabilitant's previous knee-related diseases will affect the rehabilitation self-efficacy.	Supported
$H1_c$	A rehabilitant's gender will affect the rehabilitation self-efficacy.	Supported
$H1_d$	A rehabilitant's age will affect the rehabilitation self-efficacy.	Supported
$H1_e$	A rehabilitant's use experience with motion capture tools will affect the rehabilitation self-efficacy.	Supported
$H2_a$	A rehabilitant's exercise habits will affect perceptions of system usability.	Supported
$H2_b$	A rehabilitant's previous knee-related diseases will affect perceptions of system usability.	Supported
$H2_c$	A rehabilitant's gender will affect perceptions of system usability.	Supported
$H2_d$	A rehabilitant's age will affect perceptions of system usability.	Supported
$H2_e$	A rehabilitant's use experience with motion capture tools will affect perceptions of system usability.	Supported
$H3_a$	A rehabilitant's exercise habits will affect rehabilitation achievement.	Supported
$H3_b$	A rehabilitant's previous knee-related diseases will affect the rehabilitation achievement.	Supported
$H3_c$	A rehabilitant's gender will affect the rehabilitation achievement.	Supported
$H3_d$	A rehabilitant's age will affect the rehabilitation achievement.	Supported
$H3_e$	A rehabilitant's use experience with motion capture tools will affect the rehabilitation achievement.	Supported
H4	The self-efficacy and the system usability have a relationship.	Supported
H5	Self-efficacy will affect the rehabilitation performance.	Supported
H6	Different perceptions of system usability will result in different rehabilitation performances.	Supported

For testing hypothesis H4, a correlation coefficient is performed to test the association between the rehabilitation self-efficacy and the perceptions of PRS usability. There are significant and positive correlations between the rehabilitation self-efficacy and the perceptions of PRS usability (p<.001).

The Mann-Whitney U test is performed to test the statistically significant disparities in different rehabilitation performances, measured as knee score and function score among rehabilitants with different self-efficacy and perceptions of PRS usability.

The results shown in Table 11 indicate that there are significant differences in self-efficacy and perceptions of PRS usability with different knee scores (p<.05) and function scores (p<.05). Rehabilitants who achieved a better performance generally had higher perceptions of PRS usability and self-efficacy.

For testing hypotheses H5 and H6, a linear regression is also used to determine the factors in rehabilitation performances. The results shown in Table 12 indicate that self-efficacy affects both knee scores and function scores. Table 13 results show that PRS usability also causes different rehabilitation performances on both knee scores and function scores, supporting hypothesis H5.

Finally, to prove that PRS intervention is effective and using it to make rehabilitants more confident about finishing the rehabilitation process, an independent samples t-test is performed to examine the statistically significant disparities in rehabilitation achievements of knee score, function score and self-efficacy between the experimental group and the control group. Table 14 results show that there are significant differences in rehabilitation achievements of the knee score (p<.05) and self-efficacy (p<.05) between the experimental group and the control group. Also, all research hypotheses are significant, as shown in Table 15.

Findings

This study aims at investigating how different rehabilitation self-efficacy levels affect rehabilitation achievement and tries to reinforce rehabilitant self-efficacy by using a game-based approach to make the rehabilitation processes more interesting in order to enhance the rehabilitation achievement.

Participants are divided into experimental and the control groups. The participants in the experimental group use a PRS to assist in their daily rehabilitation and fill out the questionnaire as the basis for exploring the association between variables; the control group performs general rehabilitation processes and the rehabilitation data results are collected in order to ascertain whether the use of a PRS is significantly effective for rehabilitation assistance. The findings of this study are summarized below.

Demographic variables

The demographic variables related to the findings are integrated as follows:

(1). There are significant differences in self-efficacy, system usability and knee scores between male and female rehabilitants. Men have more confidence in finishing the rehabilitation process and more quickly learn unfamiliar systems than women. Our demographic variables present the same results as the Reinen & Plomp (1997) study, demonstrating that gender has different information technology use and implementation ability, and that men have a better rehabilitation achievement than women. The result is similar to the study of Vincent et al. (2006) in that gender differences will account for different results in rehabilitation.

(2). The younger participants (age ≤ 65) start a PRS quickly, and their acceptability is also higher than the older group's. Similarly, age is related to the achievement of computer-based tasks; younger people have a higher ability to learn new systems (Kubeck et al., 1996). The rehabilitation process is easier for younger participants, compared with older ones; older participants seem to have lower confidence in rehabilitation. The knee score and function score reveal these differences. Younger participants have a better recovery status, which is consistent with the result that older adults have a slower recovery than younger people (Vincent et al., 2006).

(3). Predictably, participants who have experience in using motion capture tools are handier with a PRS, because they are familiar with similar devices. Because rehabilitation uses similar devices, they think the rehabilitation process should be easier to finish. The results suggest that similar experiences will affect user's self-efficacy in a similar fashion (Bandura, 1977).

(4). Participants with regular exercise habits have a better response to a PRS, because they have better physical coordination and controlling a PRS is easier for them. Since participants with regular exercise habits would more readily accept the intervention of a PRS, they have more confidence in their rehabilitation. Agreeing with the results of an earlier study (Sallis et al., 1988) it was found that regular exercise habits affect a person's confidence. In this study, participants with regular exercise habits had better rehabilitation achievements. Similarly, this study indicates that exercise had an effect on cartilage metabolism, and participants with exercise habits might have better cartilage metabolism, causing a more successful and speedier rehabilitation (Beckwée et al., 2013).

(5). Rehabilitants without any knee-related diseases had greater PRS usability, possibly, because they had greater knee function, enabling them to handle a PRS more easily. Also, their self-efficacy of accepting a PRS intervention is higher. The results, that disease would affect the body's mentation, and that mentation would affect self-efficacy, are the same as in Bandura's study (1977). Without any knee-related diseases, rehabilitants have better rehabilitation achievements. The result is consistent with a similar study in that previous arthroplasties affect the duration of inpatient rehabilitation (Dauty et al., 2009).

(6).

Self-efficacy and PRS usability

The results show positive correlations between PRS usability and self-efficacy. When rehabilitants think a PRS is approachable, accepting one as a rehabilitation intervention might make them feel that the process is not too difficult, which would

Figure 10. The difference of Knee score, Function score and Self-efficacy between the control group and the experimental group

allow for a higher confidence in finishing the process. The result is similar to a study in the education field in that self-efficacy and perceived usability had positive correlations (Holden & Rada., 2011).

Effects of intervention

For demonstrating that a PRS is helpful for rehabilitation achievements, a control group was set up to compare the rehabilitation outcomes with the experimental group. The results shown in Figure 10 indicate that the experimental group achieves a higher knee score than the control group. Although the two groups' function scores have no significant difference, the result might be caused by an insufficient sampling. Collecting more samples may cause significant results. Based on the above discussion, the participants' perception of system usability, self-efficacy and demographic variables are used to predict the rehabilitation achievement.

CONCLUSION

This study develops a PRS for assisting patients with their rehabilitation treatment. The developed system allows patients to strengthen their self-efficacy through a game-based rehabilitation environment and allows them a faster and more complete recovery. The PRS is a physical rehabilitation system which contains a kicking game, operated with a Kinect sensor to help rehabilitants improve their performance.

This study explores several factors in rehabilitation achievement, like self-efficacy, a user-friendly system for helping rehabilitation and different demographic variables. It confirms that these factors actually affect TKR rehabilitants with their rehabilitation achievement. A PRS is indeed able to strengthen self-efficacy and improve rehabilitation outcomes. These findings can be referenced for related research in designing auxiliary tools and helping physical therapists improve rehabilitant performance. These findings also recommend that patients should have the operation in the early stages and get into the habit of exercising to insure a better rehabilitation outcome.

In the result of this study, there are three highlights to explain the contribution of this study. This paper aimed to investigate how Physical Rehabilitation System (PRS) to improve patient rehabilitation effectiveness. The highlights of this paper shows below:

(1). Proposed a gamifying PCA-ANFIS emotions model based rehabilitation system for rehabilitants easily to use it.

(2). Investigated the performance of total knee replacement (TKR) rehabilitation by proposed system.

(3). Investigated the Self-efficacy and System usability influences effectiveness of rehabilitation, and PRS acceptance by rehabilitants.

In the future, more data should be collected so as to abate the problem of insufficient sampling, and to make the results more accurate. Although, rehabilitation systems for different diseases are being considered for development, some device limitations still need to be addressed. For example, a Kinect sensor cannot currently capture finger movements. Also, more diverse rehabilitation games can be designed, offering rehabilitants various and attractive features from which to choose.

There is a limitation in the study in that the experimental group took 30 minutes of traditional rehabilitation, plus a 10-minute PRS; the different rehabilitation time for the two groups may have affected the rehabilitation achievement, but these were performed in strict compliance with hospital policy.

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