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Development of A Persuasive and Universal Wearable Device to Promote Healthy Behavior And Enhance Exercise Self-Efficacy

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Abstract

Exercising is a primary activity to prevent diseases and strengthen the immune system. Unfortunately, people often find it challenging to have healthy behavior by exercising regularly. It is caused by having less exercise knowledge, equipment, time and space availability, exercise partner, and poor physical conditions. This behavior problem could make people vulnerable to illness. Therefore, this research aims to develop a wearable device to assist users' exercise activity and to encourage self-efficacy exercise. The device development method was a combination of persuasive design, universal design, and rich experience design. The persuasive approach aims to design the product to change the behavior problem into the behavior goal; the universal design principle ensures that the device suits various user characteristics, and rich experience design generates a positive experience from negative emotions. This research has invented a smart exercise band that acts as an exercise instructor, partner, and reminder that recommends various personalized exercise programs according to the user characteristics (gender, age, physical condition, schedule, and other preferences). The device was evaluated using Task Completion Method, Retrospective Thinking Aloud, and Perceived Persuasiveness Questionnaire to assess the usability, persuasiveness, and experience. The evaluation results confirm that the product is usability, effective persuasion, and positive experience.

Keywords: Behavior Changes, Exercise, Persuasive Technology, Universal Design, User Experience, Wearables.

INTRODUCTION

Health is one of the essential things in life since humans cannot perform daily activities if they are not healthy. Health is defined as a state of complete physical, mental, and social well-being, and not merely the absence of disease [1]. According to the hierarchy of human needs, health is one of the most basic needs of safety and security [2]. Unfortunately, the rapid development of human life often makes their activity more complex. The people's life complexity often makes them less concerned about their health yet tend to focus on material aspects.

As it is known, preventing the disease is much better than curing it. Habituating healthy behavior is the key to prevent many diseases. One of the essential healthy behaviors is to have a well-organized exercise activity [3]. Some studies elucidate that a lack of exercise raises obesity, diabetes, cardiovascular disease, deep-vein thrombosis, and metabolic syndrome [4]. However, globally 23% of people aged 18 years old and above lack exercise [5]. People aged 5-17 years old should do physical activities at least 60 minutes per day and exercise at least three times a week, while people aged 18 years old and above should exercise for at least 150 minutes per week of light exercise or at least 75 minutes per week of moderate exercise [5].

Researchers conducted a preliminary study to find out the phenomenon that causes people having lack exercise. Researchers collected data using a questionnaire for 153 respondents (range of age = 7 to 67 years old) in Asia who never or rarely exercise to find the leading causes. Researchers found that 90.1% of respondents know that exercise can make their bodies healthy and prevent many diseases. However, only 24.9% of participants have exercise behavior following the WHO recommendation. From the rest, 11.1% people who exercise 5-6 times a month, 32% people who exercise 3-4 times a month, 28.1% people who exercise 1-2 times in a month, and 3.9% people who never exercise. On average, the respondents exercise for 15-60 minutes at one time. There are some reasons why people do not like exercising, such as lack of exercise knowledge, lack of equipment, lack of time availability, lack of exercise partner, and poor physical conditions. Our preliminary research shows that the exercise problem is real and needs to be solved immediately.

People need to have self-efficacy exercise to perform their exercise activities. Today, many people cannot commit to exercising because it has a lower priority than their work or education. Some people also think that exercise is strenuous, such as the elderly or people with disabilities. This notion could reduce the motivation and ability to exercising. Besides, it could be overcome by knowing what kind of exercise activity is suitable for users' abilities, conditions, or preferences.

The rapid development of technology has changed

the way people work, form, and manage their lives [6]. The use of technology is a significant effort to gain product advantages [7]. Therefore, researchers used wearable technology to overcome the behavior problem mentioned previously. Currently, several types of research in wearable devices, health, or exercise were found. Matthews has found some persuasive features to promote health [8]. Zhao scrutinized how mobile devices influence people's health behavior change to influence people's health behavior [9]. Seifert found the use of mobile devices for physical activity monitoring [10]. Helbostad developed health applications to promote active and healthy aging [11]. Based on the preliminary research, researchers observed no previous research using the combination of methods to develop a wearable device to change people's exercise behavior. Some devices have been invented to support people in exercising. Unfortunately, most current devices proposed the features for people who currently love exercising so that it has no persuasive and universal nature to persuade people who rarely exercise. Therefore, the novelty of this research is how to use the combination of persuasive technology, universal design principle, and rich experience approach in developing a smart wearable device to promote healthy behavior and enhance self-efficacy exercise.

METHOD

This research used a persuasive design, universal design, and rich experience design approach [12]. The persuasive design approach focuses on designing a product or service that helps users achieve expected behavior [13]. Sometimes, people have to change their prior behavior to get a better life. Therefore, researchers could develop a product or system to encourage them to change their unexpected behavior. In the Fogg behavior model [13], three main factors affect human behavior change: motivation, ability, and trigger.

Persuasive design is much better when combined with universal design principles so that the product can be used well by various user characteristics. Universal design is a design principle to create a product that different people efficiently use. The universal design's main principles are equitable, flexible use, simple and intuitive use, perceptible information, tolerance for error, low physical effort, and size or space for approach [14]. Because the exercise problem occurred in various population segments, researchers used these universal design principles to develop our device.

Developing a product that can change the behavior of users with various characteristics is not easy. Researchers have to persuade them through many product features while maintaining a positive user experience for the interaction. User experience is what users feel when using a product or service. Researchers realized that the persuasive approach is susceptible to a user's negative experience in the product planning process. Researchers used the rich experience design approach to harness negative emotions to overcome this susceptibility to generate a positive experience. A rich experience approach is a design approach that aims to develop a product that can generate a rich experience by using negative emotions [15]. Rich experience is a mix of positive and negative emotion that brings a positive experience resulting from the interaction. The steps consist of adverse emotion selection, emotion elicitation, and emotion reversal. Researchers used the approach to take advantage of negative emotions in persuading the user.

The wearable device has the primary function of a user's exercise activity supporter to promote healthy behavior and enhance self-efficacy. The behavior problem observed is unhealthy behavior and less exercise, whereas the behavior goal is high self-efficacy exercise. To ensure that the device is developed well, the systematic product development steps as can be seen in Figure 1.

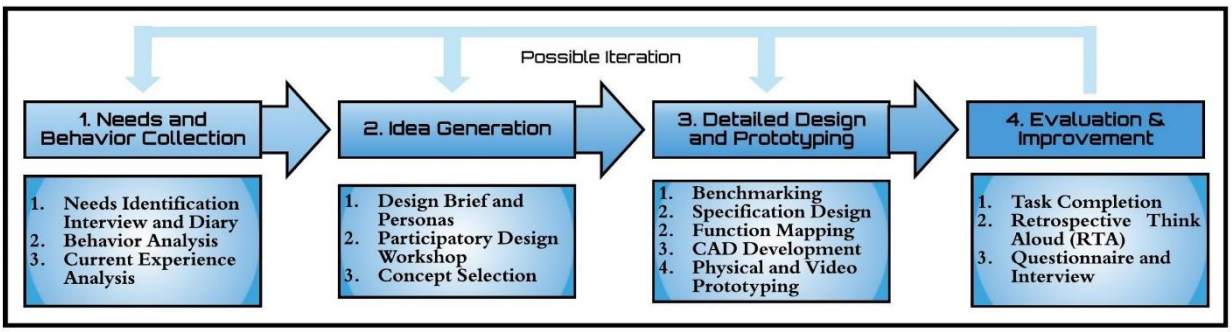

Figure 1. Product Development Steps

RESULT AND DISCUSSION

Needs and Behavior Collection

One main principle that should be remembered when researchers develop a new product is user-centered. It means researchers have to develop every product that is suitable for what our potential users need. This first step of the development process aims to gather all needs and behavior analysis related to our wearable device development. Researchers used unstructured interview and diary methods in this stage to ensure that all needs and behavior were captured as our data for product development. The participant criteria were people of various characteristics and ages who have a behavior problem. The interview method aims to dig all needs from the participants to enhance their self-efficacy exercise through our device, whereas the diary method aims to observe the existing behavior of participants to dig the root causes of their behavior problem. Researchers gave the diary to each participant for about one week. They should fill the diary with their daily exercise experience. There are some questions about their exercise in the diary to guide them. After the participants had submitted their diaries, researchers interviewed them for approximately 20 minutes each.

Researchers got 30 participants aged 12 - 76 years old; three of them were disabled people. Based on the data gathering, there were hundreds of needs statements from all participants. Second, some people like to exercise alone, while other people like to exercise together. Therefore, our device should accommodate both preferences. Third, to increase their motivation and ability, the device should bring a challenging experience. The challenging experience tends to impact users negatively; therefore, researchers used the rich experience approach to overcome this. Based on our preliminary studies, most participants feel that most existing exercises tend to be difficult, monotonous, and boring. Therefore, the challenging experience is chosen to persuade users to have self-efficacy exercise.

Idea Generation

Researchers have input data from the previous stages, such as the project's mission statement, need statements, current behavior analysis, and some qualitative considerations about the product idea. At this stage, researchers design a workshop with the participatory design method. The goal of the participatory design is to include all stakeholders in the design process [16]. The design workshop aimed to determine the best concept to facilitate people doing exercise activities. The design workshop was followed by four groups, which each group consisted of one potential user with a behavior problem and one expert designer who has capabilities in the field of HCI and industrial design. Each group produced one concept of an exercise support device. Before conducted the design workshop, researchers had created a design brief and personas. The design brief consists of a detailed explanation of the aim and scope of the project, the need statements, behavior problems identified, and the researcher's concerns. The Personas contains some illustrations of potential user's characteristics. The design brief and personas aim to synchronize the perception of all design workshop participants.

After the design workshop, researchers screened and scored the design concepts to get the best design concept. The process was conducted based on three selection criteria, which are persuasiveness, universality, and experience. Researchers used the screening and scoring method [17] to choose the best concept based on the designer team and the potential users. Researchers selected the feasible design concepts based on market opportunity, technology feasibility, and ability to solve the behavior problem in the screening stage. Researchers omitted 2 out of 4 design concepts in the screening stage. In the scoring stage, researchers refined the two design concepts that had passed the screening stage, then asked 30 potential users to choose the best one based on the ability of each design concept to meet their needs. The chosen design concept was a smart hand band that can be a personal assistant for the user in performing the exercise activity.

Detailed Design and Prototyping

After getting the final concept, researchers performed a benchmarking to see the pros and cons of other devices with similar functions. Researchers had benchmarked some platforms such as smartwatches and exercise apps on smartphones. As a result, researchers got valuable references for designing our product in terms of features, dimensions, functions, and procedures. This process also facilitated us to develop what differentiators Researchers should give to make this product compete well in the market.

Based on the concept developed, researchers designed the function and the specification of the Smart Exercise Band through brainstorming based on

data. Researchers built a function mapping diagram that contains the device's system to explain how the device is working. Figure 2 shows the 'BlackBox' function mapping of the device.

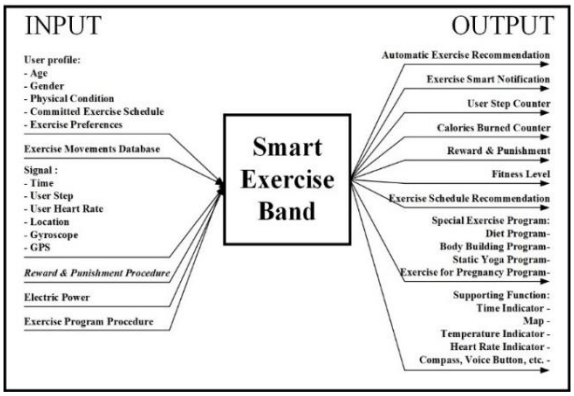

Figure 2. Function Mapping of The Device

The Smart Exercise Band has the primary function of a personal instructor, partner, and reminder for doing their daily exercise activity. This device will provide exercise movement and schedule recommendations according to the user characteristics and preferences (age, gender, physical condition, exercise schedule commitment, and personal preferences). The exercise movement recommendations will be provided at the committed time they are made. The device will give a personal fitness target sufficient exercise time based on the WHO exercise recommendation. Another prominent feature is a remarkable exercise program that provides exercise recommendations and health tips related to the user who has special exercise needs, such as the exercise program for pregnancy, diet, bodybuilding, and yoga.

Besides its primary function, this device can monitor heart rate and movement so that the user can not fraud this device. It helps users show how many steps are in their daily activities and calories burned for each exercise. The reward and punishment system is also added to provide a challenging and satisfying experience. The reward is earned when users commit to their program, whereas the punishment is earned if they ignore their exercise program. Besides, other functions, such as time, GPS, temperature, heart rate, and compass.

The smart exercise band provides more than 300 exercise movements learned from the literature and discussed with some physiotherapists and doctors in Indonesia. Researchers created a systematic algorithm to map all the exercise movements based on fitness with various characteristics. To simplify the movements and encourage the user, all exercise movements provided do not require the user to use any tools.

The device's algorithm will fit all exercise movement recommendations with the user characteristics they input in the setting menu since it has a remarkable ability to program user's exercise activity based on their profile. They have to input their profile based on gender, age, physical condition, preferred exercise schedule, and other exercise preferences. This intelligent system can increase the motivation and ability to exercise. It also makes the device universal since different people can use this device well.

The Smart Exercise Band is divided into three main parts: the head unit, the upper strap, and the lower strap. The head size is adjusted to the width of the human hand, which is generally around 65 - 110 mm [18], and compared with the benchmark's dimension. The voice button aims to provide notification or instruction in sound for users with visual limitations. The power button aims to turn on/off the device by pressing it for four seconds. The power button can also function to turn the screen on and off by pressing a while. The device consists of some main components, such as an LED touchscreen (40,5x34,44 mm), microprocessor, 195mAh LiPo battery, speaker, vibrator, PPG sensor, gyroscope, GPS, pedometer, head case, upper and lower hooked strap, and many more. The weight is about 50 grams with head face dimension 45x38,58x12,55 mm. The head case is made of ABS plastic coated with chloroprene rubber, while the straps are made of chloroprene rubber, and the buttons are made of stainless steel alloy. Figure 3 shows the CAD of the device's hardware.

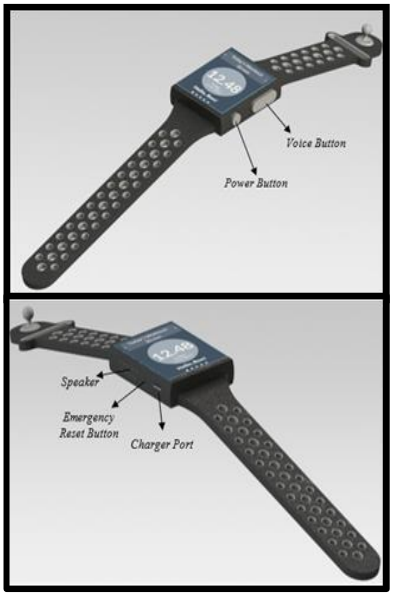

Figure 3. CAD of Smart Exercise Band

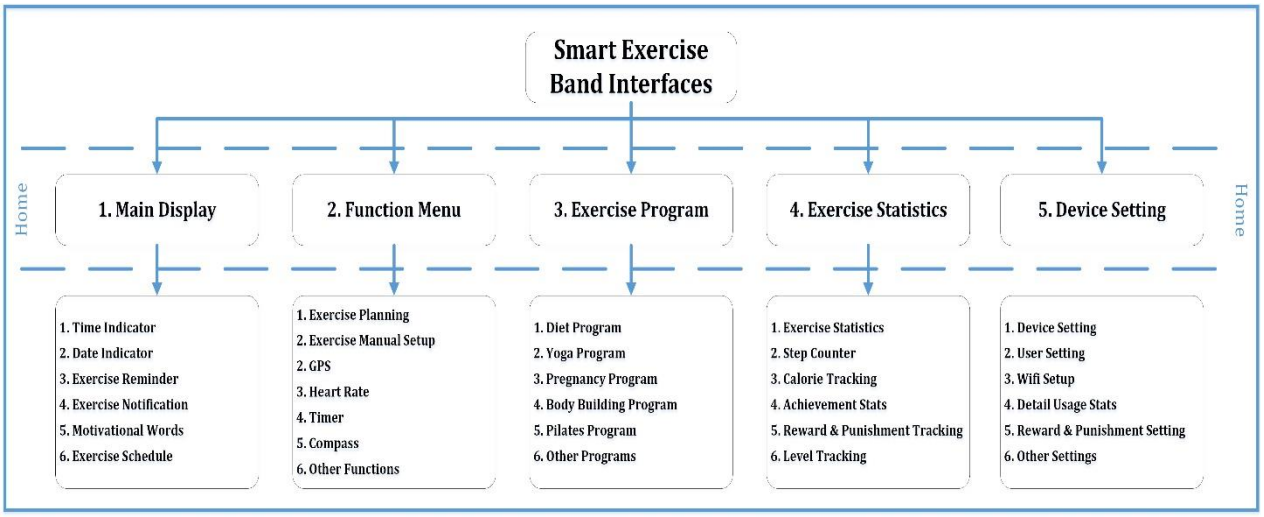

Figure 4. Interface Main Flow of The Device

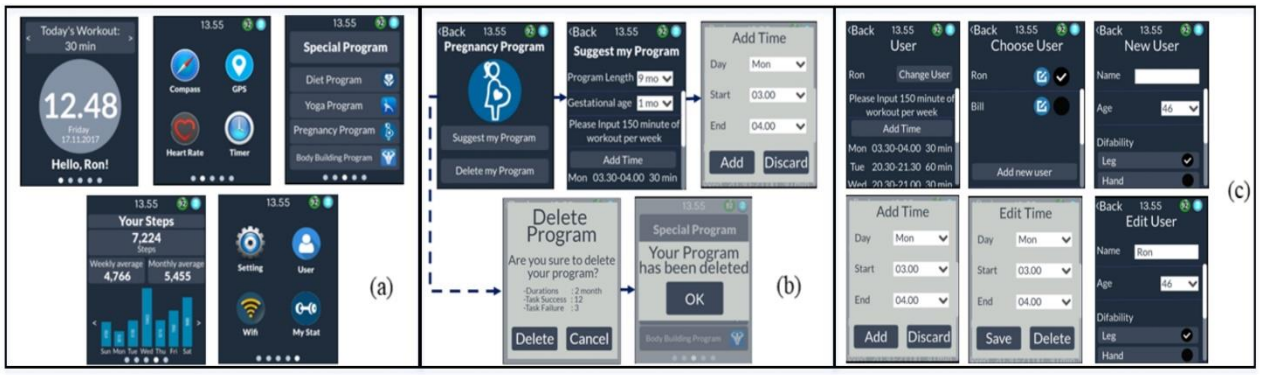

Figure 5. Some Main Interfaces: (a) Home Interface and (b) Example of Special Exercise Program (c) User Characteristics Setup

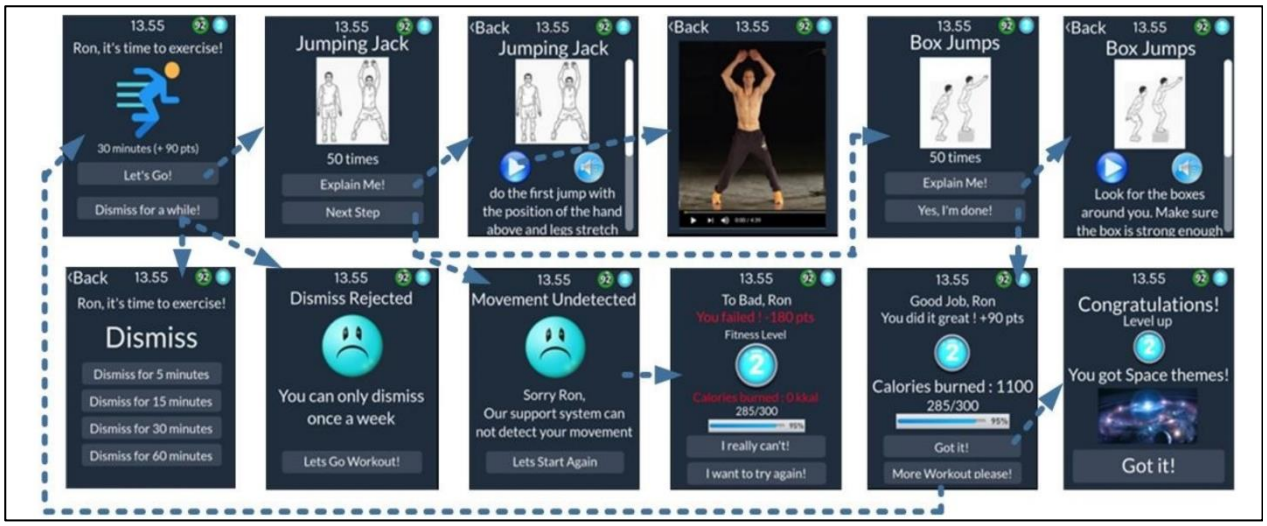

Figure 6. Example of Some Exercise Recommendation and Notification Interface

Researchers also designed the device interface to ensure good persuasiveness, universality, and human-computer interaction. The Smart Exercise Band consists of five sliding home interfaces: Main Display, Function Menu, Exercise Program, Exercise Statistics, and Device Setting. The interface and the exercise program would be updated periodically and automatically through the device's wifi connection. The interface flow of the device software is shown in Figure 4, while some primary interface examples are shown in Figures 5 and 6. After designing the hardware and software of the device, researchers conducted a preliminary evaluation to ensure that the resulted design had met our objectives.

Three main features aim to persuade the user. First, the device persuades users to exercise by the periodic notification reminder in text display, beeping sounds, or intensive vibration. The user can dismiss the notification once in each exercise activity for up to 60 minutes. Second, the device also can perform the reward and punishment system. Each time the fitness level increases, the user will get various rewards, such as screen themes, souvenirs, accessories, and many more. This unique feature will raise the user's motivation and challenge them to enhance self-efficacy exercise. Third, the last design feature to persuade is the exercise instruction and suggestion tailored based on user's profiles. This feature will increase the ability and motivation to have self-efficacy exercise.

The universal aspect of the device is integrated within the ability of the device feature, dimension, and interaction to be used and accessed well by various population characteristics. Researchers developed numerous functions to accommodate different gender, ages, physical condition, and cognitive ability. These functions are automatic movement instruction to suit every user profile; simple or tool-less exercise movement to break the limitation of conventional exercising; special exercise programs to accommodate special needs; one-time setting for all subsequent exercise for scheduled activities; and multimodal exercising assistance accommodating users with impairments.

The positive experience on the device is manifested in many interfaces using icons and commonly motivational words, the reward and punishment system based on fitness level, and the random exercise recommendation that makes the user feel challenged to do the following movements. The random movement also makes the exercise more fun and varied.

As the final step, researchers made prototypes to communicate all features and facilitate the evaluation process. Prototype one was a physical prototype that aimed to facilitate the human-device interaction for the evaluation process. Prototype two was a video prototype explaining all device features that aimed to communicate all usage procedures and features of the device.

Evaluation

To assess the design result, researchers evaluated the prototype of the Smart Exercise Band. Researchers focused on evaluating three aspects: usability, persuasiveness, and user experience of the device. The evaluation was conducted on 14 participants (8 adults; 2 elderly; 2 kids; and 2 disabled people; a range of age: 7 - 67 years old) who have a problem with their exercise behavior. Researchers had asked each of them to watch the video prototype and use the band to do some tasks for about 30 minutes before starting the evaluation. Researchers evaluated using Task Completion, Retrospective Think-Aloud (RTA), and Perceived Persuasiveness Questionnaire (PPQ) methods.

Researchers conducted a field study to observe the users' interaction with the device in their daily context and activities. Researchers asked the participants to do several tasks using the device and measured their completion rate for every task. Each participant was asked to carry out 13 tasks related to product features for two days. The summary of tasks are: (1) put the device on hand ; (2) turn the device on; (3) explore the home menu; (4) enter user profile; (5) set up exercise schedule; (6) perform the instructed exercise activities; (7) arrange the diet exercise program; (8) access heart rate after exercising; (9) use a compass to look north; (10) use GPS to see the route to his/her home; (11) runs for 3 minutes after setting the timer; (12) see exercise statistic; (13) turn off then remove the device.

Researchers also evaluated the device with a PPQ [19] to measure persuasiveness. The questionnaire consists of 9 questions using a Likert scale (1: strongly disagree; 5: strongly agree) that assesses three factors: effectiveness, quality, and persuasion capability. The effectiveness factor measures how the system could change user behavior into the target behavior; the quality factor measures how the system delivers persuasive messages accurately and reliably. The capability factor measures how the system could motivate users to change their initial behavior.

Last, researchers interviewed the participants to get a more detailed assessment from the user's view. The

interview was conducted using an unstructured interview by asking some topics such as how they think the device persuades them to have healthy behavior and enhance self-efficacy exercise; how they think the device is easy to use by all people of different ages and physical conditions; and their experience when using the device. Some captures of the evaluation process can be seen in Figure .

Based on the task completion results, 10 participants have correctly performed all tasks, whereas 4 other participants managed to finish the tasks with some mistakes. Two elderly, one kid and one adult who rarely used a wearable device made the mistakes. The elderly had some difficulties in understanding the instructions given and setting the profile. Based on the questionnaire results, researchers found out that, on average, the participants rated the device performance 3.93 for the persuasiveness aspect, 3.83 for the universality aspect, and 4.20 for the positive user experience aspect can be said to be good. Researchers found 73% positive responses and 27% negative responses about the device's persuasiveness, universality, and user experience based on the interview results.

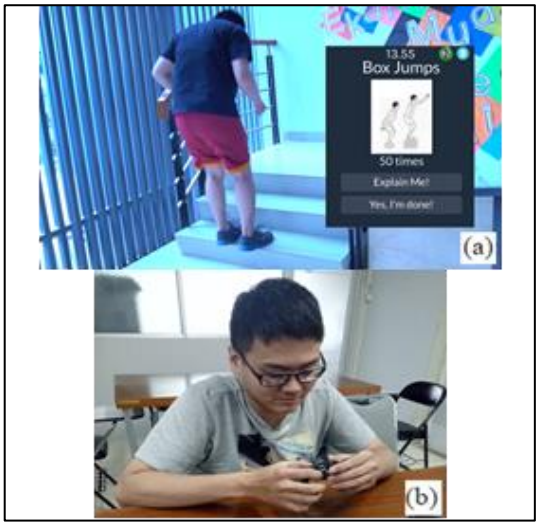

Figure 7. Some evaluation captures; (a) Performing the exercise instruction; (b) RTA process

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Based on the RTA and the interview result, researchers concluded that the device can be used well and has good functionality, persuasiveness, universality, and user experience. However, elderly users still need a slightly longer learning process than ordinary people. Therefore, the device tutorial could be a solution to learn the device better and faster. The tutorial can include introducing the device's essential features, especially when entering the device's user profile and schedule. Besides, two more things that need to be improved based on the user's views are the inner frames on the upper and lower strap should be made slightly curved and rigid to ease the user to reach the end of the strap when attaching the device to his/her hand and the device should be produced with a variety of sizes and with a more aesthetic design.

CONCLUSION

In this research, researchers have developed the Smart Exercise Band as a persuasive and universal wearable device to support people in healthy behavior and enhance their self-efficacy by exercising with a positive experience. This device serves as an instructor, partner, and reminder of user exercise activity with recommended exercise movements according to their profile. It also provides the exercise program for special needs, the step counter, persuasive exercise notification, fitness rewards and punishments, and other supporting functions.

This research has combined persuasive, universal, and rich experience design to create a wearable device that promotes healthy behavior and enhances self-efficacy exercise. The persuasiveness of the device is given in the form of instruction and recommendations of challenging exercises so that the user will feel satisfied when using the device. Besides, fitness level, reward, and punishment system can also motivate the user. The user can compete with other users to achieve a better fitness level. The universality of the device is represented in adaptable exercise instructions according to user profiles, light exercises that anyone can do, a voice button for users with hearing impairment, easy usage, use of intuitive attributes, and special population exercise programs. The device can overcome the behavior problem by giving a challenging experience through its features.

Researchers can improve the algorithm to generate an optimal exercise recommendation for different people by considering more relevant factors for future works. The development approach of this research can also be applied to develop other products or services that focus on helping people achieve the intended behavior goal by generating a positive experience.

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