Familiarity Design in Exercise Games for Elderly

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Abstract

Rehabilitation exergames aim to help the elderly recover from their deteriorated capabilities due to aging. Research suggests that exercise games (exergames) may effectively engage the elderly in physical activities. However, new technologies and devices normally used to develop the exergames may be over complex and difficult for the elderly to use, mainly because the hardware and software components involved in modern exergames appear unfamiliar or even alien to the elderly mentally. Moreover, the elderly consider the investment to acquire the unfamiliar technology is too high. Therefore, the study of familiarity issues of the elderly is important and necessary to guide the interaction design of new technologies so that they can be built upon the elderly's prior knowledge of real world interactions to help the elderly to apply their existing skills to a new domain. In this paper, we propose three dimensions of familiarity design and the approach to design familiar exergames for the elderly. By following this approach, we hope to increase the usability of the exergames that the elderly can naturally interact with. For case study, we introduce the design principles followed when implementing the Virtual Escape Exergame to illustrate the usage of our proposed familiarity design approach to develop an exergame in a familiar virtual environment for the elderly.

Keyword: Exercise Game, Familiarity, Usability

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I. Introduction

The number of older persons has increased substantially in recent years in most countries and regions. The growth of the aging population is projected to accelerate in the coming decades [1]. Senior citizens will encounter various health related issues as they age, which will cause the reduction in their motor and cognitive capabilities.

Rehabilitation exercises aim to help the elderly to recover from their deteriorated capabilities and to become as independent as possible to alleviate both the societal and individual home's burden [2]. In order to recover efficiently and effectively, the elderly are advised to frequently take exercises according to their conditions. However, the incentive for the elderly to take exercises by themselves is often not enough. Traditional rehabilitation treatments are usually administrated on the one-to-one basis, which makes the treatments difficult to operate due to the high cost and the dependency on human resources. In addition, it is time consuming for elderly to travel to the clinics and they often feel isolated and bored during the traditional rehabilitation exercises [3]. As a consequence, the adherence rate to traditional rehabilitation exercises is relatively low. A study [4] reports that only 31% elderly complete the prescribed exercises, which reduce the effectiveness of traditional treatments.

Literature has shown that the advances in technology can make the rehabilitation treatment more efficient and effective [5]. New technologies such as video games, augmented reality, and virtual reality can decrease the monotony of repeated exercises and provide instant feedback of elderly's motions, which is beneficial to both the quantity and quality of the rehabilitation [6]. Video games with motion detection devices, such as Microsoft Kinect, can stimulate the elderly to take exercises by the attractive interfaces and interesting tasks. Hence, elderly can complete the exercises in the game environment with enjoyment. Exercise games (exergames) are beneficial to senior citizens and protect them from illness by providing appropriate exercises. In addition, elderly can play the rehabilitation exergames at home and other places, such as community centres, at their convenient

time. Family and community members can play together with the elderly to enhance their relationship between each other. However, the rehabilitation exergames design seldom considers the incentives for the elderly to play the exergames. It is not easy to motivate the elderly to voluntarily play the exergames unless the games are attractive enough. One of the key reasons that why exergames are not popular in the aging population is the lack of engagement [7]. New technology, such as exergames, is normally perceived as unfamiliar by elderly with the feeling of anxiety or even hostility [7]. Moreover, despite the elderly may be willing to learn how to interact with the computer, they often find the investment of personal resources is too high.

In this paper, we delineate our approach on applying the theory of familiarity on rehabilitation exergames design to engage the elderly in playing the exergames. According to the cognitive psychologists' theory [8], familiarity is “the relationship between an individual and something that individual has had considerable experience with. The experience is sufficient to advance to the development of an internal model of that something.” The feeling of familiarity is derived from an individual's prior experience that stored in one's memory. Repetition and frequency are the critical antecedents to feel familiar with something [9]. The increase of familiarity will lead to the strengthening of connections among less connected features. The elderly may feel more comfortable and willing to improve their social and functional capabilities when they encounter familiar environments such as objects, places, and sounds [8]. However, current technical products for the elderly are either specially targeted to the deficiencies of the elderly or derived from the general products to meet the particular needs of the elderly, which both fail in terms of familiarity [7]. Currently, the cohort of the elderly have little exposure to the new technologies such as computers compared to the younger generation [10]. Most of the designed software and hardware fail to consider the cultural background and experiences of the elderly, which leads to the unfamiliarity relationship between the technologies and the elderly. Our research aims to guide the development of exergames for the elderly with familiar interfaces and interactions that the elderly may have encountered in their real life. As such, we can motivate the elderly's engagement in exergames.

The rest of this paper is organized as follows. We review the related work on exergame design for the elderly and theories on the familiarity in Section 2. We present the framework of familiarity design and the methodology to design familiar exergames in Section 3. We show our Virtual Escape Exergame as a typical example of familiarity design in Section 4. In the end, we conclude this paper in Section 5.

II. Related Work

The number of older persons has increased substantially in recent years in most countries and regions. In recent years, technology advances in virtual reality, augmented reality, and motion detection lead to the emerging of exergames for the purpose of rehabilitation. These exergames aim to help the elderly take exercises in a relaxing and entertaining atmosphere without the feeling of monotony and isolated in traditional exercises. We review some well-established exergames in Section 2.1. Moreover, in Section 2.2, we review some research on familiarity that have been conducted to increase the engagement of the elderly to new technologies, which show the effectiveness of familiarity in motivating the elderly.

A. Exergames for Elderly

Elderly may suffer from various impairments as they age, particularly the reduction of the motor and cognitive capabilities. Research shows that repetitive exercises can provide a sufficient amount of stimuli to remodel the elderly's brain and hence regain a better control on one's motor capability [11]. Other studies on exergames indicate that technologies, such as video games, can enhance the elderly's motivation of repetitive exercises and help them to recover from the decreased motor and cognitive capability more efficiently [5] [12]. Compared with the traditional rehabilitation exercises, programmable systems, such as exergames, can provide attractive graphical virtual environments, which can be designed in varying ways to encourage the users to become more engaged, immersed, and motivated in the rehabilitation exercises [13].

Exergames are usually implemented on the wirelessly controllable platforms, such as Nintendo Wiimote and Microsoft Kinect. Study shows that Wiimote is more acceptable by the elderly people compared with other types of game controllers [14]. Kinect is also popular due to its non-intrusive and controller-free features. These wireless devices can reduce human intervention and enhance the motion of the elderly in an unrestricted environment. As such, they offer a sense of self-determination, provide a feeling of independence, and improve the quality of elderly's life [15].

Because exergames are relatively new for majority of the elderly, some studies in the literature focus on enhancing the incentives for the elderly to play the exergames. In terms of exergames design, Rizzo and Kim emphasized the visibility, feedback, and identification of the target users as three important human factors [5]. Balaam et al. indicated that entertainment-oriented exergames are effective to motivate the elderly to play the exergames [16]. Similarly, Alankus et al. proposed that motion-based games, which combine motion-detection with fun in the exergames, can stimulate people to exercise with the games voluntarily [6]. Burke et al. identified that meaningful play and challenge are the two principles of game design that have particular relevance to motivate the elderly. Moreover, they pointed out that positive feedback, such as high numerical scores, can be the gratifying incentives to encourage the elderly to continue the exergames and reach a particular goal [17]. On the other hand, the negative feedback, such as failure signs, should be used discretely in case of discouragement to the elderly [17].

Besides the impairment in motor capability, the elderly may also suffer from memory loss and other mental problems, which can substantially affect their capability to interact with the real world [18]. In order to exercise both the elderly's physical and mental capabilities, various exergames should incorporate physical exercises together with cognitive challenges. For example, the SilverBalance exergame designed by Gerling et al. aims to recover the both elderly's bodily and cognitive impairments [19]. The game's sensitivity can also be adjusted according to the degree of reduction on an individual's visual and cognitive capabilities.

From prior research on exergames, we can identify that exergame is more acceptable to the elderly in the home environment, which can help them recover from the deteriorated capabilities in a relaxed and enjoyable atmosphere. In order to benefit more number of elderly, we need to improve the motivation for them to play exergames.

B. Literature on Familiarity

Tognazzini suggested that the operation of an interactive system is best achieved by means of a metaphor or analogy, which indicates the importance of familiarity [20]. Being familiar with a system means we are ready to operate it in an appropriate way based on our prior experiences [21]. Sufficient experiences may lead to the development of an internal model, or stereotype, about how one expects something to work [8].

Demirbilek and Demirkan [22] studied the impact of the environment on aging factors of the elderly. They found the elderly prefer to live in their familiar environments in the “getting older'” phase of their life, which is a prime important aspect to design their homes. For elderly, familiarity can increase the safety, usability, and attractiveness of the environment. Barry [23] also encouraged the incorporation of familiarity into the home design to bring positive changes. He suggested that home design should preserve the character attributes of each specific elder individual. Boger et al. [24] assessed the impact of familiarity on the use of different faucet designs by elderly with dementia symptoms. The results showed that familiarity plays a substantial role in faucet usability (effectiveness, efficiency, and satisfaction) for the elderly. Boger et al. indicated that these trends may well be applicable to other products and activities.

Besides the home environment, the theory of familiarity can be also applied in interactions between new technologies and the elderly. Leonardi et al. [7] designed the acceptable domestic technologies for elderly based on the concept of familiarity. They found the interface functioning depended on a variety of secondary elements, such as menus and dialog boxes, which are technical components that the elderly are not familiar with. Therefore, Leonardi et al. designed the interaction modality based on few rules of interaction and natural gestures, such as replacing the ``erase'' command with

scrubbing the finger. Hollinworth and Hwang [10] designed the tmail application with familiar visual objects (e.g., email messages shown in the inbox resemble paper envelopes) and behaviours (e.g., messages and images can be moved by touching and sliding). All the elder participants found the visual objects in this familiar interface easy to understand and they can quickly master how to use tmail. The experimental results indicated that familiar interfaces can help in orientating the elder users with an application.

Prior research showed the effectiveness of familiarity in helping the elderly to understand and interact with the new technology, which encourages us to adopt the familiarity considerations in exergame design. Based on the literature review, we can identify that familiarity can increase the effectiveness, efficiency, and satisfaction when elderly interact with new technologies.

III. Methodology of Familiarity Design in Exergames

Familiarity design in exergames can help the elderly to interact with the system naturally and increase the usability of the games. In this section, we propose the methodology of familiarity design in exergames for the elderly.

A. Framework of Familiarity Design

Familiarity helps in encouraging the elderly to learn and understand how to interact with the new technology by using their existing knowledge learned in their everyday life. This means not only the interfaces of the systems should appear familiar, but also the style of interactions in the whole system should fit the elderly's past experiences and capabilities. Moreover, good familiarity design can evoke the elderly's memories and corresponding emotions [25]. For instance, in the interface design of a system, the familiar objects and scenes that the elderly already experienced before may activate their corresponding memories and similar emotions as before.

Based on the literature review of familiarity design on the adoption of new technologies for the elderly (see Section 2), we propose the framework of familiarity design for new technologies, which consists of the following three dimensions [26]:

1) *Symbolic Familiarity*: Objects, scenes, and activities, which frequently appear in elderly's daily life, should be infused into the system.
2) *Cultural Familiarity*: Traditions, patterns, concepts, and rituals, which exist in the elderly's culture, should be infused into the system.
3) *Actionable Familiarity*: Actions to interact with the system should be consistent with the actions used when interacting with the real world.

The identified three dimensions can help us design familiar interfaces and styles of interactions in all systems for the elderly. During a holistic system design, each part of the familiarity design can be categorized into one of the three dimensions. Moreover, each dimension can play a different role in improving the usability of the system for the elderly. Depending on the degree of the fidelity of simulating the three dimensions of familiarity to the real world, any system can be evaluated by whether they are familiar enough to the elderly.

B. Design Familiar Exergames

Based on the aforementioned three dimensions of familiarity design, we propose our specific approach on familiar exergame design. Other than the metaphorical and analogical connection of the exergames to the real world, familiarity design also requires the exergames share the same background of concepts, meanings, and practices with the elderly. Therefore, we indicate three specific aspects, namely representation, manipulation, and meaningful design, which lead to good familiarity design in exergames. The relationship among the three aspects and the major familiarity dimensions of these aspects are shown in Figure 1.

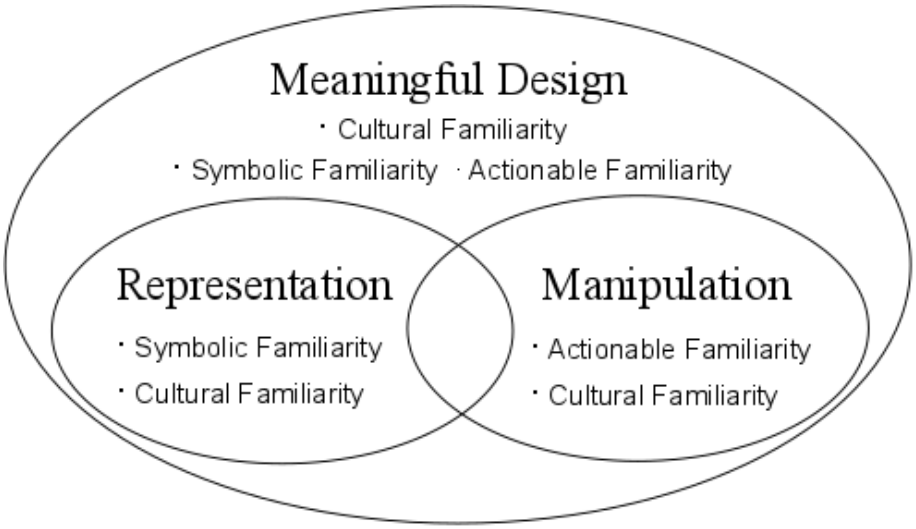

Figure 1. Illustration on the three aspects of familiar exergames design.

Representation: Using the representation as similar as possible to the real world in exergames is an effective method to help the elderly understand the games. Representation provides the elderly the tools to interpret the system. Typical representations include the familiar environments such as objects, pictures, music, etc., which can help the elderly maximize their functional capability. Thus, symbolic familiarity is the most appropriate dimension to achieve familiar representation. Meanwhile, some concepts of cultural familiarity can also be used in the representation for the elderly with the same cultural background. On the other hand, representation does not necessarily mean duplicating the objects in real life to the exergames. Rather, we need to take advantage of the novelty in the digital world and at the same time, follow elderly's real-life knowledge and experiences during representation design.

Manipulation: Manipulation indicates how the elderly manipulate the objects in exergames. One of the advantages in exergames is that the elderly can act in the same manner as they do in real world rather than point and click using various computer accessories. However, the physical motions required in exergames should be consistent with motor patterns the elderly use in real world. For example, wrist rotation can open the door handle in the virtual environment, which shares the same cognitive model learned in real world. Therefore, actionable familiarity should be considered in the manipulation design. Each manipulation design should refer to the real life elements. However, even

if the representation is familiar to the elderly, the interactions and manipulation in exergames may not be familiar to them. In particular, exergame designers should pay more attention when there is no logical relationship between the motions and the outcomes in exergames.

Meaningful Design: Familiar exergame design requires not only the imitation of real world, but also the stimulation of the elderly's memories and emotions. For instance, the interfaces with specific concepts and meanings may activate elderly's memories and practices experienced before and invoke their past emotions. With the sense of anticipation during exergame playing, guided by the past experiences, the elderly will find the interactions recognizable and enjoyable. Therefore, meaningful design means to select the contexts and domains in exergames which are not only objectively and socially suitable, but also related to the elderly's past experiences and emotions. Meaningful design requires to take all the three dimensions of familiarity into account. However, we should pay more attention to the cultural familiarity because the same design may have different meaning for elderly from different cultures. Meanwhile, due to the diverse personal experiences of each individual, meaningful design may vary from person to person. Thus, the personalization of meaningful design should also be taken into consideration.

Kaplan and Kaplan [8] indicated that familiarity could promote the cognitive processes of the elderly and increase their confidence in interacting with new technologies. The elderly will perform better and guide their own behaviours when they face familiar objects and environments. Hence, by applying the aforementioned three aspects of familiarity design in exergames, the elderly may not need to learn new technological language or adapt to unfamiliar environments. Alternatively, they can utilize their prior experiences, which are learned from non-technical areas, to complete the basic exercise tasks embedded in the exergames. Another advantage of our proposed approach is that the elderly can take less cognitive effort to accomplish the exercise requirements, which is more practicable for the elderly with cognitive difficulties. With all these advantages, we aim to follow this approach to design the exergames that elderly can immediately understand and enjoy.

IV. Virtual Escape Exergame

The Joint NTU-UBC Research Centre of Excellence in Active Living for the Elderly (LILY), Nanyang Technological University, Singapore, is one of the world's first research centres focusing on interactive digital media empowered ageless aging. LILY has initiated a number of interactive exergames for the elderly using Kinect as the non-intrusive motion detection device. We follow the approach of familiarity exergame design presented in Section 3 when we developed the Virtual Escape Exergame (VEE) to help the elderly exercise their motor and cognitive capabilities.

Figure 2. A camera view of the virtual home in the VEE.

Conventional escape game requires players to escape from imprisonment by exploring and exploiting the surrounding environment. Due to the involvement of puzzles, players need to solve the problem with repetitive attempts in most cases while exercising their cognitive and physical capabilities, which makes the escape game suitable and effective for the elderly's exercises. VEE promotes various types of interactions between the elderly and the virtual confined environment (a living room, see Figure 2). Another advantage of VEE is its high flexibility, which enables the elderly to perform various actions, such as pulling out drawers, pressing buttons, turning knobs, etc. This kind of extendable game flexibility makes VEE more challenging and less boring. To solve the in-game puzzles, the elderly need to interact with various objects in the living room with body movements in front of the Kinect cameras. Therefore, VEE exercises not only the body movements of the elderly but also their critical thinking skills. Table 1 lists some selected familiarity designs

implemented in VEE and their related dimensions. The rest of this section introduces each aspect of these familiarity designs in detail.

Table 1. Heading and text fonts.

Representation	1) Furniture design (*Symbolic & Cultural Familiarity*) 2) View outside the windows (*Symbolic Familiarity*) 3) Room layout (*Symbolic Familiarity*)
Manipulation	1) Selecting chests in the TV (*Actionable Familiarity*) 2) Wiping the desk (*Actionable Familiarity*) 3) Pulling the drawers (*Actionable Familiarity*)
Meaningful Design	1) Background music: Xinyao (*Cultural Familiarity*) 2) Encouragement characters (*Symbolic Familiarity*)

A. Representation Familiarity in VEE

In VEE, we develop a familiar virtual environment for the elderly to achieve representation familiarity. The escape room is designed as a typical living room (see Figure 2) that the elderly encounter every day. The furnishings and objects in the virtual room are displayed as similar as possible to the real world. Hence, there will be no overwhelmed feeling when the elderly first play this exergame. Due to the familiarity with the virtual environment, the elderly may find it is easy to know where the various objects placed when working on a given task.

Other than the familiar representation of the integral virtual room design, we also pay attention to the familiarity design of each specific object in the room, especially those objects that the elderly need to interact with. With the guidance of symbolic and cultural familiarity, we figure out how to achieve the representation familiarity. For example, in stead of modern furniture, we implement the old fashion furniture in the virtual room. The elderly are familiar with these old fashion furniture and easy to know how to interact with them. Moreover, some parts of the virtual room, such as the decorative painting on the wall and the view outside the windows, are not design to be interacted with. However, we still use familiar pictures and scenes to decorate the environment in order to increase the elderly's home-like feel of the exergame.

B. Manipulation Familiarity in VEE

In exergame design, task design is the most important part regarding exercises for elderly. Manipulation familiarity should be embedded in the tasks of all exergames. In terms of VEE, it requires the elderly to proceed with a series of movements in the correct order to unlock the puzzles, which is more difficult than the common exergames because players may need to repeat similar movements. With the requirement of sequential tasks, VEE may appear difficult for the elderly. Therefore, familiar manipulation is essential in VEE to help the elderly to quickly understand and complete the tasks.

Figure 3. An example of task design in Virtual Escape Exergame.

In order to incorporate the actionable familiarity into the manipulation design, the tasks we designed in VEE mainly come from the elderly's daily life scenarios, which can encourage the elderly to transfer their daily life knowledge into the virtual environment. For example, when the elder player has to find the information from the television in the game (see Figure 3), they just need to follow the steps of watching television in their home: Open the television and then change channels to find the correct chest. The difference lies in that they may not have a remote controller. All they need is to use their arms to complete the tasks in front of the Kinect cameras, which is beneficial to their physical exercises. In order to design more familiar tasks for the elderly, we also transform some simple daily housework into the VEE tasks. Because the elderly are familiar with these housework, they should be able to quickly understand the tasks based on their experiences. For example, we design a table coated in dust (see Figure 4), where the required information to complete certain tasks

is hidden beneath. The elderly can wipe the table as they normally do at home to obtain the information.

Figure 4. Wiping task in Virtual Escape Exergame.

With the manipulation familiarity design, we hope the elderly would find it easy to act appropriately in order to complete tasks, which would improve their confidence in continuing to play VEE. Hence, manipulation familiarity can increase the adherence of exergame playing among the elderly.

C. *Meaningful Design in VEE*

Altman and Werner indicated that environment can serve as a cue to remind people to connect present and past, and to link experience and memory [27]. Their findings bring us the idea that familiarity may not mean to display ordinary objects, but to present meaningful artefacts and environments to the elderly.

Meaningful design requires the exergame designers to investigate the commonly shared past experiences and cultures of a particular region where the exergame will be deployed. The appropriate exergame design for one region may not be meaningful for the elderly from another region. Therefore, after investigating the past experiences of the elderly in Singapore, we find the Singaporean pop songs (Xinyao, URL: https://en.wikipedia.org/wiki/Xinyao) back in the 80s are the commonly shared memory of Singapore's elder generation. Majority of the elderly are fond of Xinyao after experiencing the charm of it. Thus, we select some popular Xinyao songs as the background music of VEE to stimulate the elderly's past feeling of passion or comfort.

Meaningful design may vary from individual to individual. Therefore, personalization of the exergame is also important. Personalized familiarity can be defined as aligning or customizing the

attributes and features in order to enable an individual to develop relevant knowledge or mastery. We customize the encouragements used in VEE for each individual elderly. Specifically, we choose the photos or videos of the elderly's family members, such as their children and grandchildren, while displaying the supportive messages to encourage the elderly to continually play VEE. The elderly will be more attracted by VEE with these familiar faces appearing in the exergame from time to time.

V. Conclusions and Future Work

Exergames are proven to be effective and efficient to motivate the elderly to take exercises and stay healthy. Familiarity is a highly important issue for the interactive system design, such as exergames. We suggest that the metaphors of the daily life objects and the cognitive models can help the elderly understand the interactivity of the exergames. In this paper, we define the framework of familiarity design in three complementary dimensions. Based on our framework, we further propose three specific aspects of familiarity design in exergames for the elderly. Moreover, we introduce the Virtual Escape Exergame that we developed for the elderly. For each familiarity aspect of this exergame, we give a typical example in the context of VEE. By following our design approach, VEE will be more explicit and attractive for the elderly by exploring their prior experiences and knowledge.

For future work, we prepare to improve the viability and effectiveness of our approach on familiarity exergame design by conducting case studies on VEE. We will follow the feedback of the case studies to refine our design methodology in order to make it more complete and simpler to use.

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