Fit Islands: Designing a Multifunctional Exergame to Promote Healthy Aging for Chinese Older Adults

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Abstract –

Emerging economies are ill-prepared to deal with population aging. Uncontrollable events such as the COVID-19 pandemic and regional conflicts have exacerbated the plight of older adults. The consequent development of smart aging offers endless possibilities for improving the quality of life and health of older adults. In this paper, the authors propose a universal approach to designing a health-promoting Exergame system in the format of a virtual village for emerging economies to cope with aging populations. To verify the feasibility, the authors designed an expandable Exergame called "Fit Islands", using China as a case study. Based on the initial demonstration the authors conducted functional tests. The result is that Fit Islands can meet the development objective of motivating Chinese older people to increase their physical activity, providing initial evidence of the feasibility of an Exergame system to promote healthy aging in emerging economies. The application of Fit Islands demonstrates the feasibility of the universal Exergame development method, which can, in principle, provide comprehensive and practical guidance for other countries.

Keywords –

Aging in China; COVID-19 Pandemic; Digital Technology; Exergame; Health; Population Aging; Serious Game; Silver Economy; Smart Aging

1 Introduction

Compared to developed countries, the growth rate and magnitude of the elderly population in developing regions are much higher [1]. The large population base, strong economic growth, abundant resources, and enormous market present both opportunities and challenges [2]. With the rapid ageing of the population, problems have arisen such as a huge gap between the rich and the poor in urban and rural areas, an unfriendly society for the older adults, empty nesters, a rapid increase in the number of chronically ill patients, and an underprepared health-care system [3]. The COVID-19 pandemic and regional conflicts have undoubtedly exacerbated the physical and mental ill health of the older adults. Lockdowns and other restrictions on travel make older adults, who are already socially isolated due to family relationships, social connections, marital status, Digital gap, etc., more likely to develop a sense of loneliness, which in turn triggers psychological problems such as depression and anxiety. These psychological problems can easily lead to a decline in the quality of sleep, in-creased incidence of cardiovascular and cerebrovascular diseases, and can lead to cognitive decline in the older adults, etc., which directly and negatively affects the quality of life of the older adults [4,5].

Smart ageing offers new possibilities to deal with the problem of ageing population. By utilising advanced Internet, cloud computing, wearable and other new-generation information technology tools, it is possible to build urban Internet of Things systems and urban information platforms for home-based, community-based and institutional elderly care, to maximise the satisfaction of the needs of the older adults in terms of social participation, leisure and culture [6]. In smart cities, digital entertainment interactive applications such as age-friendly games have great potential to enhance the quality of life and physical and mental health of the older adults. In recent years, a new digital technology has been introduced to motivate people to engage in physical exercise, and is known as Exergame [7]. Exercise has potential benefits for improving the physical health, cognitive abilities, mood, personality and overall well-being of older adults [8,9]. In the context of ageing societies, Exergame is no longer just for teenagers or game enthusiasts, but offers new ways of coping with the problems of ageing as a tool for disease prevention and health education for older people.

The aim of this study is therefore to try to incorporate Exergame's game format to design a virtual village that encourages physical activity, using China as an example, breaks down spatial isolation and crosses the digital gap for older people in emerging economies (Figure 1). By proposing a design methodology for the health promoting Exergame system, new solution ideas are proposed for different emerging economies to cope with the problem of population ageing.

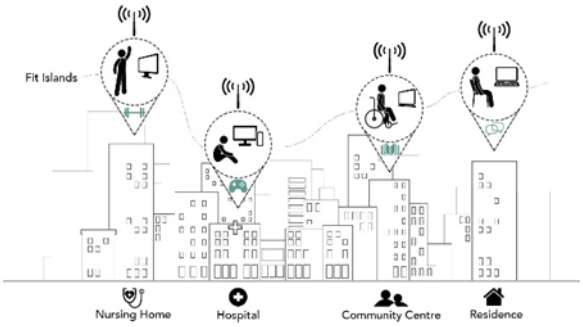

Figure 1. Fit Islands breaks spatial isolation and provides a health promoting virtual platform for Chinese older adults

2 Background

Exergames typically utilize various types of sensors as input devices. Cameras, as input device, along with corresponding algorithms, can enable motion capture functionality, allowing the possibility of playing Exergames without holding or wearing input devices [,10].

2.1 Existing projects

Gerling et al. in 2010 explored design guidelines for sports game design for older adults with a game called SliverBalance [11]. Chartomatsidis et al. 2019 developed an Exergame called Fruit Collector, based on the Kinect sensor and developed using Unity for 3D game world design, demonstrating the positive impact of Exergames on improving physical health in older adults [12]. In 2017 a virtual therapeutic gaming system called SilverFit 3D further demonstrates that treating older adults through Exergames is an accepted, effective and potentially cost-efficient approach through a system based on scientific research and clinical practice that can develop rehabilitation protocols and targeted exercise programmes for older adults [13]. The REACH research project conducted by Hu et al. included an Exergame system called the ActivLife Gaming Platform, which senses and assists with a smart device called the PI2U-iStander, designed to prevent falls in older adults through physical activity and cognitive training [14]. SliverBalance takes into account the physical conditions and the cognitive limitations of older adults. Fruit Collector interviewed orthopaedic and physiotherapists to assess the game's movements and focused on building older adults' confidence in the game. SilverFit 3D can create over 1.2 million exercises based on scientific research and clinical practice. The flexibility and adaptability of the PI2U-iStander smart device in REACH also ensure the safety of older adults during play. However, these games also have some drawbacks, for example, SliverBalance and Fruit Collector have a single content and do not take into account the long-term motivation of the players. The SilverFit 3D and REACH systems are very expensive, require a medical resource system or a smart device and are not widely used in everyday life.

2.2 Inclusive design

In the 1980s and 1990s, scholars began to make proposals for age-friendly games. Weisman and Whitcomb, after studying the effects of age, suggested that gameplay should include adjustable game speed and difficulty and easy-to-use interface design [15]. Ijsselsteijn et al. also suggested in their study of digital games in the early 21st century that visually adjustable game interfaces should be considered. For example, fonts, colours and contrast, providing a presentation that incorporates both dynamic resources and multimodal feedback in addition to text [16]. Flores et al. expand on this by arguing that it makes sense to combine appropriate cognitive challenges, simple user interfaces and motivational feedback in the design [17]. Gerling et al. also suggest that older players should be given the possibility to adjust the difficulty of the game, the speed of the game and the sensitivity of the input device [11]. A large proportion of today's older adults have limited experience with digital games and therefore Exergames should be designed to minimise the number of steps required to complete tasks and reduce cognitive load, enhance the scientific, safety and practicality of the game, thereby increasing the user adaptability of the game system.

The above content of the background research generated guidance and insights into the following research methodology. The special situation of countries with emerging economies requires researchers to analyse the current situation in the country with a large amount of data before designing, which in turn determines the main concepts of the game, its purpose and users, its functionality, interfaces and interactions. The development and the test of Demonstration can further ensure the scientific validity and credibility of the study.

3 A universal method for health promoting Exergame system design

The process of Exergame development for emerging economies is proposed in Figure 2.

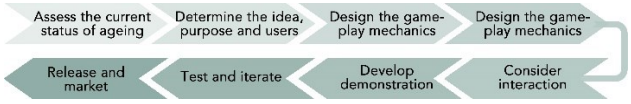

Figure 2. A universal development flow for health promoting Exergame systems for emerging economies

4 Fit Islands

4.1 The current status of ageing in China

China, as a representative emerging economy, has a huge population base. The improvement in medical conditions and the one-child policy have directly contributed to population aging in China [18,19]. Generally, individuals aged 65 and above are considered older adults. However, in China, based on the retirement age of 60 for men (55 for women), individuals aged 60 and above are classified as older adults. Data shows that even using the age of 65 as the threshold, China's population aging exhibits significant scale, depth, and speed. The speed of population aging in China has surpassed that of any other country in modern history. By the end of 2022, China's population decreased by 850,000 compared to the previous year, marking the first negative growth. The rapid decline in the number of women of childbearing age and the fertility rate suggests that China is entering a period of normalized population decline [20]. It is projected that by 2057, the peak of China's elderly population aged 65 and above will reach 425 million, accounting for 32.9%-37.6% of the total population. The current status of population ageing in China has the following main aspects:

- Age structure and health: The age structure of China's elderly population is young. The health status is at a low level, and the number of people suffering from chronic diseases is increasing rapidly [21,22].
- Education and informatization levels: as education levels rise, adaptation to digital technologies shows a polarized phenomenon [21,23].
- Economic status: China's older adults are growing old before they get rich. The wealth disparity in different regions is very large. Older adults rely mainly on savings, children, continued work and property [24].
- Psychological health: In China, cultural traditions emphasize family systems and collectivism. The phenomenon of elderly people who have lost their only child and empty nesters has intensified, shaking the Chinese tradition of family social support for the older adults and exacerbating the social isolation and loneliness [25].
- Leisure and recreation: Chinese older people's leisure activities are mostly sedentary, and their interest in sports is generally at a low level. In terms of physical activity, square dancing is the preferred choice for them [26].
- Living space: Most Chinese older adults currently have their own private living space. However, the construction of public facilities for the older adults, such as activity centers, physical exercise centers, barrier-free facilities, is still incomplete [27].
- Policy and Smart Aging: China is promoting a three-tiered elderly care system, with plans for 90 per cent of older people to stay at home, 7 per cent in community centers and 3 per cent in institutional care centers. China's elderly care products and ageing services have not yet developed to the extent that they can meet the needs of the ageing population, and are not yet an alternative to 'family pension' [28].

4.2 Determine the main idea, objectives, and users of the game

"Fit" represents physical and mental health. The game design will need to meet the following objectives:

- Adaptable: All older adults can use the game. Membership will be set up to provide extended games for various numbers of players to ensure the games can be adapted to different scenarios.
- Affordable: The game will be played without external wearable devices. It will only require a computer with a camera to play, aiming to minimize game costs.
- Elderly-friendly: The design will be inclusive of different levels of cultural, linguistic, visual, and auditory abilities, creating a user-friendly interface and game experience for the older adults.
- Enjoyability: To increase the motivation, the game will have many functions, but will also provide practical assistance to the target users, such as adding valuable health knowledge in the game.

4.3 Design the gameplay mechanics

In Fit Islands, players will assume the role of lively animated characters living on their own floating village (see Figure 3). Players can visit shops, cultivate crops, interact with friends on their contact lists at the post office, and play games at the game centre.

Figure 3. Fit Islands' Poster

The specific process can be summarized as follows: Initial game installation - Game instructions - Account creation - Main interface - Game map - Gameplay - Points and health knowledge. Elderly players who may be less familiar with information technology can receive assistance from family members or caregivers during the initial game installation (see Figure 4).

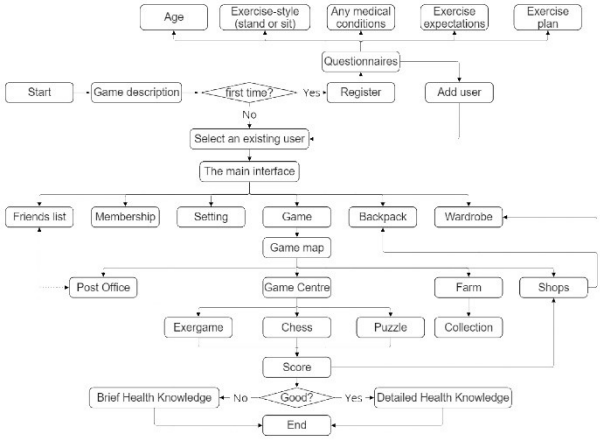

Figure 4. Functional flowchart of Fit Islands

The game will be designed to include two forms of exercise, full-body standing exercise and upper-body exercise (see Figure 5). The points-based incentive system, allowing players to use points to redeem various items in the game store. At the end of each gaming session, players will receive different health knowledge. To simplify the preference settings for older adults, the game will employ individual user profiles and automatically match game content. The game can accommodate two users for free in total, and after each game session, the progress and user data will be automatically saved. In the settings, older adults can freely adjust game content, language, colour brightness and contrast, font size, and more. Furthermore, Fit Islands is expandable, allowing different membership levels to enjoy larger game maps, more game varieties, and accommodate additional independent user profiles and services.

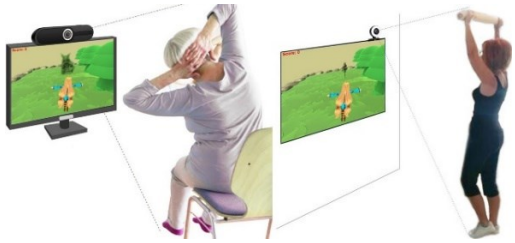

Figure 5. Two forms of games: (a) full body standing movement; (b) upper body movement

4.3.1 Exergame design

In Fit Islands, the shadow representing the action will gradually move closer to the game character from behind. The degree of overlap between the shadow and the game character will determine the player's score. The movements in Fit Islands will primarily focus on preventing cardiovascular diseases [29], enhancing muscle strength [30], and improving flexibility and balance among the older adults [31]. Fit Islands will categorize and assess the difficulty of all expert-evaluated movements, and these movements will be combined in a default sequence to form a set of progressively challenging game levels. Each level will last approximately 10-15 minutes by default and follow the sequence of warm-up, exercise, and stretching for the movements. An option to adjust the difficulty level will be added at the end of each game, which allows the game to maintain a basic level of challenge while providing inclusivity, ensuring the autonomy and safety.

4.3.2 Health knowledge

Authors have collected knowledge on diet, exercise, living habits, self-monitoring, disease prevention, psychology, etc., such as: knowledge of nutrients and proper dietary combinations [32], exercise and exercise precautions, how to maintain good sleep, how to prevent cardiovascular and cerebral vascular diseases [33], how to maintain a good state of mind. When presenting health knowledge to older adults, it is important not to excessively emphasize the authority of the knowledge but to consider ways to make it easier and quicker for them to comprehend the information. The image on the right uses a friendly tone and presents the health knowledge through visuals and audio (see Figure 6).

Figure 6. Comparison of health knowledge

4.3.3 Business

Fit Islands has added a product point exchange and membership system, where points can be earned through farm cultivation, sports games, cognitive games, and interaction with friends. These points can be exchanged in the shop for virtual game character skins as well as some real elderly goods, such as electronic blood pressure monitors. Appropriate adverts or videos are played at the end of the game. This will attract brands, communities, nursing homes, etc. with the same target audience to place commercial ads or offer real products. Fit Islands offers three levels of membership for different number of players.

4.4 Plan the user interface and visuals

The design of user interfaces for older adults needs to take into account their habits and preferences in terms of style and aesthetics (see Figure 7). Fit Islands has been designed to meet the inclusive design principle.

Figure 7. the interface in the demonstration: (**a**) initial interface; (**b**) game description; (**c**) user registration; (**d**) interface for selecting gender; (**e**) main interface; (**f**) settings interface; (**g**) membership interface; (**h**) game map; (**i**) shop interface; (**j**) post office interface; (**k**) farm interface; (**l**) game centre; (**m**) Exergame interface; (**n**) health knowledge interface; (**o**) multiplayer interface.

4.5 Consider the gameplay interaction

Fit Islands employs an audio-visual sensory experience to simplify data and information feedback, making it easier for older adults to take in different information through voice-reading and pictures. The interface switching throughout the game mainly relies on direct mouse clicks, while the motion capture in Fit Islands avoids any wearable devices, and the game can be played simply by standing in front of a computer with a camera. Immersive interaction is an important aspect of the interaction design process in Fit Islands. In addition to creating natural scenes through ambient sounds and dynamic effects, Fit Islands also adds multiplayer online. Players can play against each other in cognitive games or complete challenges in two-player mode in exergame.

4.6 Develop demonstration

The development of the Fit Islands demonstration consisted of interface design, a motion capture program, motion pose image recognition and the creation of a 3D game world. For the motion capture part, the demonstration uses the ThreeD Pose Tracker algorithm. Motion pose recognition uses a skeleton recognition algorithm to identify imported motion pose images and display these skeletons in the image of the game character. The 3D game world for the Fit Islands demonstration was created using an open-source resource called ‘Top-down island’ from the Unity shop. The game is played from a bird's eye view and the character is controlled by running around with a right click of the mouse.

4.7 Test and iterate

4.7.1 Test

The initial testing of the demonstration for Fit Island was split into two phases. In the first phase, a 62-year-old German woman was invited to test the functionality and operation of the game after the initial demonstration was completed. After receiving feedback, the initial game demonstration was refined. The second stage was to invite 9 Chinese older adults to test the functionality and useability of the game after the completion of the refined game demonstration. The nine seniors, aged 51-77, included three women and six men. B-F, were tested in the computer room of a community centre in Yancheng, Jiangsu Province, China, G and H were tested in the activity room of a community centre in Yancheng, Jiangsu Province, China, and the other two, I and J, were tested in their homes. These older adults were asked to operate and use the game and to provide feedback on the corresponding issues (see Figure 8).

Figure 8. Field photos of nine older Chinese adults test subjects

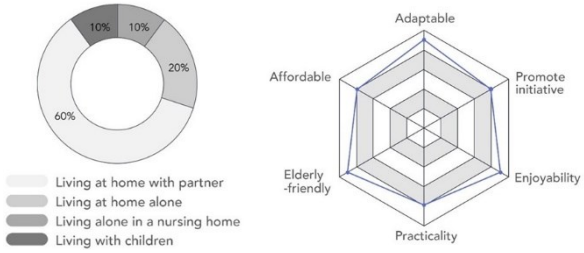

Figure 9. Analysis of test results. (a) Residency (b) Evaluation scores of the game

Once individuals' data is involved, protecting their data privacy will be critical. Therefore, the good practice for protecting individual privacy in the test is reported as follows. First and foremost, the test was conducted in a fully anonymous manner, meaning that information such as names, birth dates, addresses, and resident identity card numbers were not recorded. This approach excludes any possibility to identify any individual test participant. Furthermore, to participate in the test, all the participants were informed of the transparent purpose of the study and needed to give consent to provide their basic demographic information such as age, gender, residential address, and level of education. These measures also go in line with Guide on the Good Data Protection Practice in Research [34].

The test was conducted in the form of a questionnaire. The questions mainly included evaluation of the game interface, game content and features, and whether it is useful for health. Based on the results of ten older adults in the initial test. (see Figure 9), the following findings can be concluded:

- This system can effectively motivate older Chinese adults to exercise and increase their amount of physical activity. The initial test participants were able to complete the exercises relatively easily, and the music and scoring format allowed them to concentrate on the exercises. Many older adults said they look forward to the health knowledge.
- This system provides a free platform for Chinese seniors to communicate and play multiplayer games. The affordability and anonymous and fun way can be used as a complement to family pensions, allowing older adults to socialize more with people of their age, mentally reducing over-dependence on their children and alleviating feelings of social isolation and loneliness. Several older adults in the test expressed their enjoyment of the post office function and their expectations of the online multiplayer function.
- The age-friendly and inclusive design of this system can attract older adults to actively use the technology. Most of the older adults responded positively to the game's functions and interface, found the game relatively easy to operate and use, and expressed acceptance of the game's format.
- The system is adaptable to different devices and different scenarios. Desktop computers were used in the computer room, while laptops were used in the activity room and the testers' homes. Older adults can play the game in different building scenarios using existing equipment.

4.7.2 Limitations and Future Work

The demonstration of Fit Islands has basically realized most of the contents and functions of the game design, and in the future, it will further complete more accurate motion capture, improve the whole game's motion library and realize the function of multi-person online. The above test as an initial test of Fit Islands has already obtained positive results, but the sample is small the demonstration lacks further refinement and is only a functional test. Further testing and evaluation will require larger participant sizes and long-term follow-up observations to ensure the long-term sustainability and effectiveness of Fit Islands.

After further refinement of the game demonstration, several older adults will be invited for further testing ($n \geqslant 30$). A uniform site will be chosen and the test subjects will be brought together in a uniform site for testing. The future test will be divided into four main phases. The first phase of the test will be the distribution of information about Fit Islands' research objectives and planned tasks to the test participants, who will be introduced to the Exergames equipment and procedures. The second phase will divide the test subjects into a control group ($n \geqslant 10$) and an intervention group ($n \geqslant 20$). The physical and psychological conditions of the two groups will be assessed separately to ensure that the subjects are not

statistically significantly different. There are many methods of testing specifically for older adults. For example, a research team assessed the functional status of older adults using the Activities of Daily Living Scale (ADL) and the Instrumental Activities of Daily Living Scale (IADL) [35]. Mental health status can be tested using the UCLA Loneliness Scale or subjective questions [36]. The third phase will have the intervention group (n ⩾20) play the game three times a week for five weeks, either at home or at this uniform venue of their choice. Various parameters will be recorded during the game, including the time of entry into the game, the time of user creation, the time of exercise, the score of the game and whether the participant completed the game in its entirety or was launched early, etc. The control group (n ⩾ 10) will not be intervened and will live their lives according to their own way of life. In the fourth phase, the physical and psychological well-being of the two groups will be assessed again after five weeks in the same way as in the second phase. Effective proof can be derived by comparing the data of the control group (n⩾10) and the intervention group (n⩾20) at Phase 4.

After the validation, the project team plans to initiate an internet-based start-up to further promote the project and its products to as many people as possible through multiple channels in order to make a real impact. Furthermore, the start-up (i.e., online store) can potentially create an economy around elderly-focused educational and health games, where profits can in turn support future product iterations and new product development, and potentially create new jobs around the business (e.g., customer service, manufacturing, etc.).

5 Conclusion

In conclusion, Fit Islands strictly follows the generic development methodology presented in Section 3 and meets the development goal of motivating Chinese older adults to increase their physical activity. As the problem of aging continues to grow in emerging economies, the development and application of Exergame will play an effective role in the future to create a smarter, healthier, more active and fun lifestyle for the older adults. Furthermore, due to its advantages such as high flexibility, affordability, and ease of use, the proposed system can be easily integrated into larger smart city frameworks such as Dynamic Vertical Urbanism [37] to generate a comprehensive smart city experience for the aging population and beyond.

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