A Gamified Baduanjin Mobile Exergaming for Neurodegenerative Diseases Rehabilitation

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Abstract

The neurodegenerative disease has affected millions of people worldwide. Previous studies have shown that physical exercise for the short term or long term is beneficial for neurodegenerations diseases. However, physical exercise is quite boring. Digital serious games can be used as tools to help and encourage older adults to train physically and mentally. Baduanjin Qigong exercise has been observed to be beneficial for their health. In this work, to motivate older adults to practice more physical exercise, a gamification framework for the Bedaubing exercise is proposed, and based on this framework, a somatosensory parkour mobile game is proposed. The experimental testing shows that the Baduanjin Qigong exercise can be accurately recognized, and the results from the Game Experience Questionnaire (GEQ) indicate the game can increase elderly users' motivation. During play, the game, the physical movement data, and the performance data in the game are collected for training the predictive model to evaluate the risk of neurodegenerative diseases.

Keyword: Rehabilitation Game; Exercise Game Design; Gamified Baduanjin Exercise.

I. Introduction

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In many countries, the number of elderly people is rapidly increasing. The number of older persons aged 60 or over is estimated to 2.0 billion in 2050 globally. It is estimated that the share of the population aged 65 years or over will grow from 12.5 percent in 2019 to 22 percent in 2050 [1]. The growth and aging of the older adult population will be associated with an increased prevalence of chronic diseases and health issues[2]. The burden of illness related to the growth of the older adults population will require a broad and diverse healthcare workforce that can efficiently and effectively diagnose and treat patients with complicated health problems[3].

Neurodegenerative diseases such as Alzheimer’s disease, Parkinson’s disease are very ordinary among the elderly population. Based on the data from WHO, more than 55 million people live with dementia worldwide and the majorities are Alzheimer's disease and may contribute to 60-70% of cases. Early symptoms of neurodegenerative diseases are not obvious and are often misclassified as other diseases and diagnoses rely on professional equipment and medical personnel. That is the main reason why many patients received delayed, inappropriate treatment.

It has been proved that proper exercise can make the elderly healthier and happier. Exercise interventions designed for individuals with certain neurodegenerative diseases have been shown to increase aerobic capability, strength, and balance[4]. Furthermore, research suggests that regular exercise can prevent or decrease the progression of the disease in people suffering from certain neurodegenerative diseases[5-7]. Indoor exercises are useful for older adults who are either reluctant or incapable of going out. Baduanjin Qigong (also known as Eight-Section Brocade, Eight Pieces of Brocade) is one of the popular traditional Chinese qigong exercises, which has a history of more than 1000 years. It contains eight easy gesture

movements based on the theory of traditional Chinese medicine which is characterized by interplay between symmetrical physical postures and movements, mind, and breathing exercise in a harmonious manner[8]. Previous studies have shown that Baduanjin Qigong exercise benefits quality of life & sleep, balance, torso flexibility, grip strength, blood pressure, and resting heart rate[8, 9]. Yu et al. carried out a randomized controlled study to evaluate Baduanjin exercise in patients with mild cognitive impairment. The results showed that Baduanjin plus conventional therapy can greatly improve memory and cognition in patients suffering from mild cognitive impairment compared to conventional therapy[10].

However, fitness exercises including Baduanjin exercises are often very boring, that is one of the main reasons why many people cannot insist on long-term exercise[11].

Various studies have shown that exercise games are effective in facilitating older people maintain their physical and mental capabilities[12, 13]. To increase usage of exercise games by the population of older adults, mobile games for seniors should be meaningful, attractive, easy to use, usable, and motivating for technology adoption[14]. To implement this motivation, an understanding of the opinions of older adults about the growing technology is applied by many researchers. Based on these demands, in this work, we propose a game design framework for gamifying Baduanjin Qigong exercise to motivate older adults to perform more exercise.

On the other hand, studies have proved that through the analysis of the performance activities and behaviors data while playing the game, these neurodegenerative diseases can be detected and diagnosed early[15], and timely treatment can significantly delay the disease and even can reduce the patient's functional impairment, reducing their mental and economic burden and improve the quality of life in old age. In this work, the movement data and performance in-game playing are non-intrusively collected and have been further analyzed to evaluate the risk of neurodegenerative diseases.

The main contributions of this article are:

1)Propose a game design framework for gamifying Baduanjin Qigong exercise to motivate older adults to

perform more exercise.

2)Movement data and the performance data in-game data are collected, and key features are recognized and extracted for neurodegenerative diseases risk evaluation.

II. Related Works

New technologies such as digital virtual reality, video games, and augmented reality can reduce the boringness of repeated movement and provide instant feedback on movement for older adult users, which is beneficial to the quantity and quality of exercises[16]. Video games employed with motion tracking sensors, such as Microsoft Kinect, can attract users to follow the games by appealing and easy-to-understand interfaces and interesting exercise or cognitive tasks. Nowadays, an extensive variety of exercise games with enjoyable game graphics and tasks are proposed to provide both cognitive and physical exercises for users, which are shown to be more satisfying than traditional rehabilitation exercises. However, most such health-care-related exercise games are not user-friendly for older adults.

To improve the user experience for older adult users to play exercise games, Carvalho and Ishitani proposed several important guidelines for game design: follow usability heuristics and consider mobile devices limitations; understand the benefits of playing the game; avoid requiring a great deal of attention; reword fun feedback in-game playing; progressively increase the level of difficulty; offer a cognitive challenge and ensure that the older player feels proud of their abilities; avoid repetitious and monotonous tasks[17]. Familiarity is another important factor to reduce the perceived difficulty and complexity of navigation in the gaming environment and create a feeling of harmony and comfort[18, 19].

Mostly existing information applications or systems related Baduanjin are designed for novice starters to learn Baduanjin independently[20]. For all we know, there are no such systems or applications to stimulate older adult players' enthusiasm in playing Banduanjin exercise. Following previous findings on game design for the elder population, in this work, we proposed a gamification framework for the traditional

Chinese Bedaubing exercise.

To distinguish normal cognitive aging from neurodegenerative diseases is very important for detecting cognitive deficits early and providing adequate treatment to alleviate further neurodegeneration and cognitive impairment [21]. However, existing neuropsychological evaluation methods have some issues: (a) unsuitability for repeated use; (b) limited sensitivity to recognize subtle and early changes of cognition, and (c) lack of ecological validity[15]. One approach to overcome those challenges is using mobile games for the evaluation risk of neurodegenerative diseases. Mobile or tablet game-based solutions are also proposed by recent research. Pan et al.[22] designed and developed an Android mobile app to collect Parkinson's disease related motion data by the 3D accelerometer of the mobile phone, and Parkinson's symptoms severity is estimated at the cloud service. These methods need the user to play specific games and might not be widely used. Most existing methods are designed to monitor the severity of the patient and do not provide risk estimation for general end-users. In this work, the proposed method can apply to exercise mobile games which are quite popular in a home-based environment.

III. Proposed Gamification Framework

The Baduanjin Qigong exercise, which requires little space or time, uses special breathing and concentration techniques to improve the body and mind, with eight standardized movement sequences for limbs, body-trunk, and eye movements, including Eight Section Brocade[23]. The eight-section name in English are 1) Pressing Up to the Heavens with Two Hands; 2) Drawing the Bow and Letting the Arrow Fly; 3) Separating Heaven and Earth; 4) The Wise Owl Gazes Backward; 5) Big Bear Turns from Side to Side; 6) Punching with Angry Gaze; 7) Touching Toes then Bending Backwards; 8) Shaking the Body[24]. Each one of the eight movements is stipulated with a same starting position and a same ending position.

A. Baduanjin Movement Recognition

Accounting hands and legs movements[23] required in each section, in this work, the Baduanjin sequences movements are broken down into 15 Core Movements: 1) step out legs; 2) bend the knees; 3) moving legs together; 4) standing up; 5) pushing up; 6) descend hand; 7) cross two hands; 8) drawing the Bow; 9) raise hands over the head; 10) stretch two hands; 11) moving the upper body in a circle; 12) hitting out punches; 13) restore from punching gesture; 14) rising on toes; 15) drop body on heels to the ground. Each section movement can be recognized by a series of Core Movements. For example, when a series of Core Movements of 1, 2, 5, 6, 4, 3 is recognized, we can infer the first section, Pressing Up to the Heavens with Two Hands, is played by the user.

During playing the Baduanjin exercise, the hands and legs are required to move in 6 directions, that is moving up, down, forwards, backward, left, and right. Based on the movement directions of the hands and the legs, the 15 Core Movements can be further broken down into 6 Basic Movements from the hands and 6 Basic Movements from the legs.

Accelerometers, gyroscopes, and magnetometers are the three main sensors used for detecting motion and orientation[25]. Currently, most wearable devices such as smartwatches or smart bends are widely used, and most kinds of these devices are built-in with these sensors. Previous research shows that six directions of an object's movement can be accurately recognized using the data of 3D Accelerometers, gyroscopes, and magnetometers attached to the object[26]. As shown in Fig 1, in this work, we built wearable devices in which the 9-axis motion tracking sensor is embedded for testing and experimental.

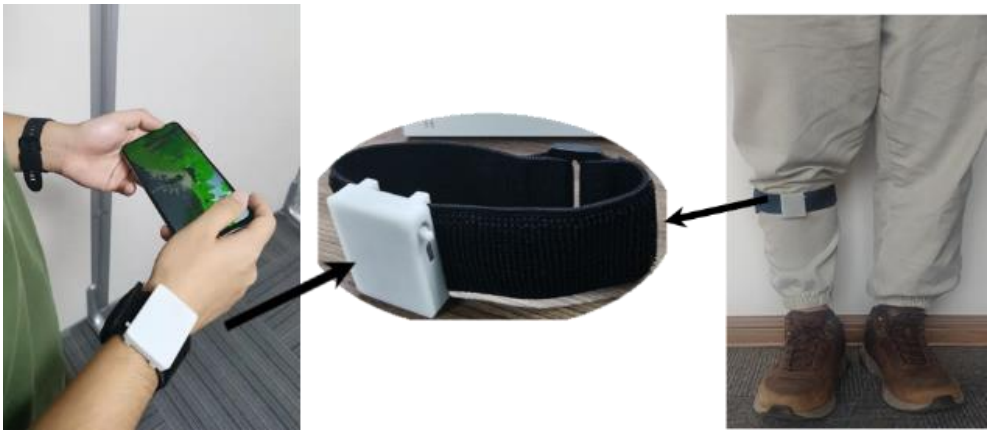

Fig 1 Wearable device for movement trucking

B. Abbreviation Game Design

Following previous findings[14, 18] on exercise game design for the elder population, in this work, we propose a gamification framework for the traditional Chinese Bedaubing exercise.

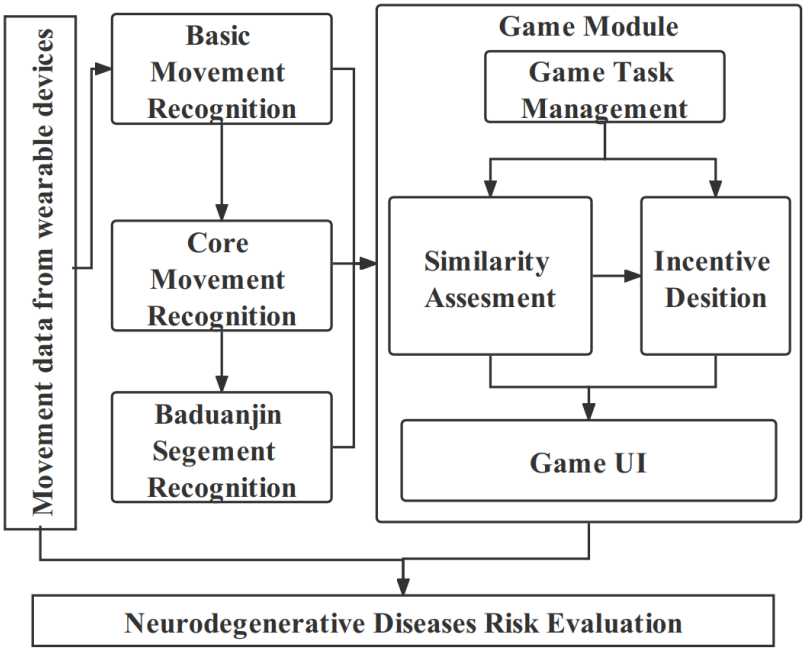

Fig 2 Game Framework

A Banduanjin theme-based mobile exercise game framework is shown in Fig 2. The game framework includes the movements data capture module, movement recognition module, game module, and the module of neurodegenerative diseases risk evaluation. The hands and legs movement data of a player is captured and collected from the wearable devices in real-time. Then

Basic Movement, Core Movement, and Baduanjin Segments are recognized from the collected movement data. The results of the movement recognition drive the avatars' action in the virtual world of the game and the similarity between expected movement is assessed. The game incentive (e.g., reward score) is decided and feedback to the player over Game UI. In the end, all the movement data and the performance data are sent to the module of neurodegenerative diseases risk evaluation to estimate the risk of neurodegenerative diseases.

Based on the proposed game framework, a Baduanjin theme-based somatosensory parkour mobile game is developed. In this game, the player is required to interact with game UI by playing Baduanjin movement or the Core Movements described in Section 3.1. Two typical screen shots of the game ar shown in Figure 3.

Figure 3 Screen shots of the Baduanjin game

The game contains eight parts corresponding to the eight sections of Baduanjin exercise. Technically, the hand and leg movement data can be captured by most exiting commercial wearable smartwatches or smart bands. As most commercial devices do not release the raw data of movement, the wireless wearable devices embedded with a nine-axis motion sensor are designed and implemented to capture the player's hand and leg movement data as shown in

Fig 1 for testing and evaluating the designed game.

III. Experiment and Results

A conclusion section is not required. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

IJsselsteijn et al. developed the game experience questionnaires (GEQ) to evaluate game experience that contains seven important components: Competence, Sensory & Imaginative Immersion, Flow, Tension/Annoyance, Challenge, Negative Affect, and Positive Affect[27]. To evaluate the game experience of the developed somatosensory mobile game. A total of 10 participants were recruited to participate in the game experience experiment. The core module of the GEQ is used that consists of 33 items which the participants are required to score using a 5-point, unipolar intensity-based answering scale (0- not at all, slightly, moderately, fairly, and 4- extremely) after playing the game. During the game plying, two pieces of the designed motion tracking sensors are attached to one of the lower legs and one of the wrists (as shown in

Fig 1).

All participates were trying their best effort to play the game, and all the Banduanjin movements were correctly recognized. Figure 4 shows the typical hand movement data of playing the Banduanjin segment one in which the hand descended (Core Movements No. 6) three times.

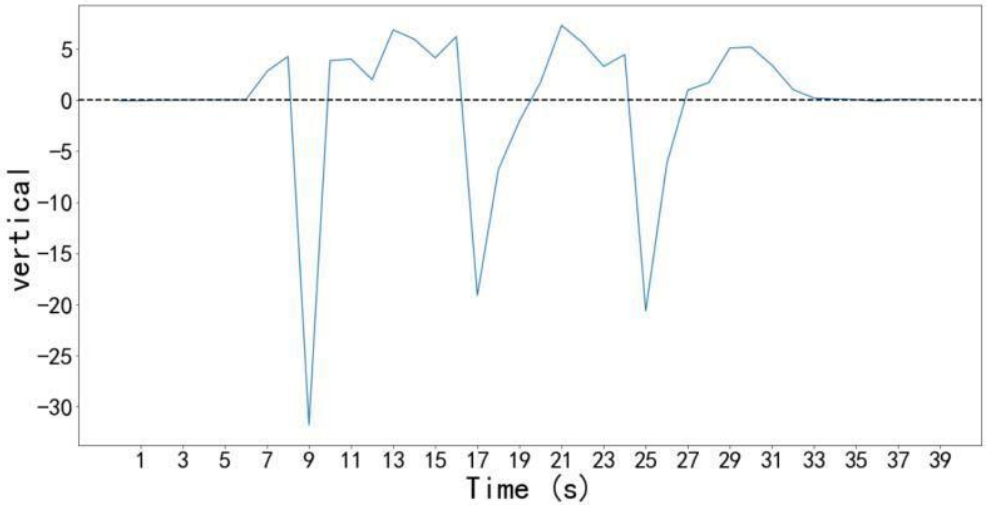

Figure 4 Hand movements in the vertical direction when playing Baduanjin segment one.

Statistic results from the Game Experience Questionnaire (GEQ) for the 10 participants can be seen from Figure 5 and Figure 6. The scoring guidelines of GEQ Core Module described in [27] were used to calculate category the scores of the seven components. As shown in Figure 5, all positive components scored average 2.5 points above except the component of Challenge which scored 0.5 points below. That means the difficulty degree of the game is lower than user's expectation. All negative components, Tension and Negative Affect scored average 1.0 points below.

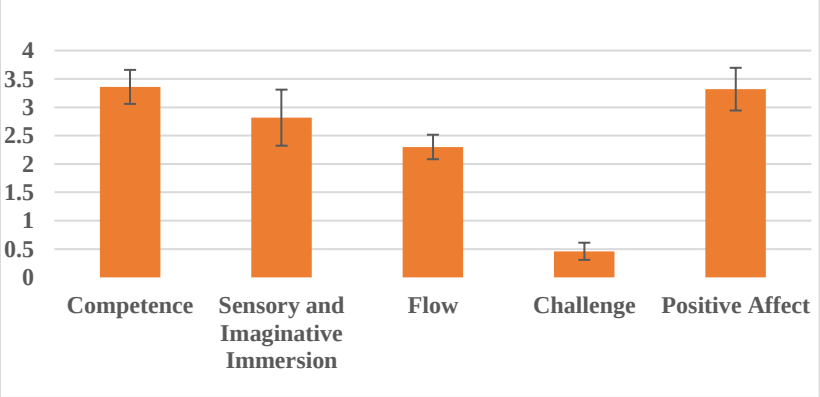

Figure 5 Mean participant scores on positive components of the GEQ's Core Module. Scale: 0= "not at all", 1= "slightly", 2= "moderately", 3= "fairly", 4= "extremely".

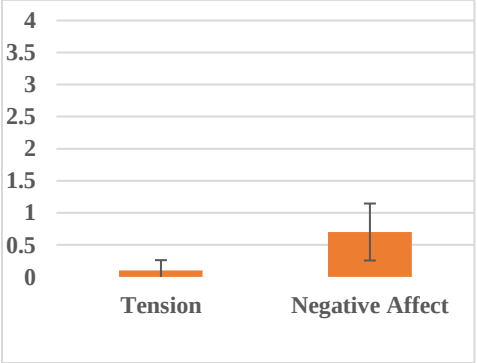

Figure 6 Mean participant scores on negative components of the GEQ's Core Module. Scale: 0= "not at all", 1= "slightly", 2= "moderately", 3= "fairly", 4= "extremely".

III. Conclusion and Future Works

A conclusion section is not required. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion.

A game design framework for gamification of Banduanjin Qigong is proposed and somatosensory parkour mobile is developed. A preliminary experimental is conducted and the game is identified to be an effective way to encourage elder adult users to play the Baduanjin Qigong exercise. The data collected during playing the game are used to extract six key features which can be used to estimate the risk of PD. In the future we will conduct the study on neurodegenerative diseases patients, as such, the ground truth data can be collected for training the model to estimate the risk of neurodegenerative disorders such as PD and AD diseases.

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