

Pumpkin Garden: A Tablet Game Platform for Parkinson's Disease Rehabilitation

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Abstract

Parkinson's Disease (PD) is one of the most common neurodegenerative disorders, threatening the living quality of over 10 million people worldwide. No cure has been found for PD. Therefore, rehabilitation plays an important role in maximizing patients' functions and quality of life for the sake of continuing to lead fulfilling lives. Physical exercise is adopted as an effective means in PD rehabilitation. However, physical exercises need to be conducted intensively over a long period of time to be effective, leading PD patients to feel mentally bored and physically tired. This reduces their motivations to persist in rehabilitation as a result. In this paper, we propose a tablet based game platform for PD rehabilitation, which is able to encourage the patients to keep on rehabilitation exercises. The patients in-game behaviors are collected and analyzed to generate reports for the patients and the clinicians to track disease progression and adjust rehabilitation plan.

Keyword: Parkinson's Disease, Rehabilitation, Game.

I. Introduction

Parkinson's disease (PD) is a one of the most common neurodegenerative disorders affecting patients' motor and cognitive functions. Patients suffer from the problems that impact their daily life,

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such as *akineisa* (difficulty in initiating movement), *bradykinesia* (reduced amplitude and speed of movement), abnormal facial expressions, postural instability, and some cognitive problems such as memory loss [1] [2]. It is estimated that there are over 10 million people worldwide suffering from PD (http://www.pdf.org/parkinson_statistics). Though some medications, such as L-DOPA and dopamine agonists, have been applied for managing symptoms and delaying disease progression, there is no cure found for PD. Therefore, rehabilitation plays an important role in maximizing patients' functions and quality of life for the sake of continuing to lead fulfilling lives. Physical exercise is adopted as an effective means in traditional PD rehabilitation. However, as physical exercise needs to be conducted intensively over a long period of time to be effective [3] [4], PD patients undergoing traditional rehabilitation exercise tend to feel mentally bored and physically tired [5-7]. This reduces their motivations to persist in rehabilitation as a result. In recent years, video games have emerged as an alternative for PD rehabilitation [5,8-14], which are able to motivate the PD patients to keep on rehabilitation exercises [15]. However, most of the existing games depend on sophisticated devices or platforms (e.g., GestureTek and IREX) to capture and track players' motions, which are expensive and require professionals for system setup. In addition, most of the games need to be played with the presence of instructors, which make them unsuitable for independent home-based rehabilitation.

In view of this, we propose a tablet based game platform to facilitate patients to have daily rehabilitation exercise in a convenient way. The tablet device (e.g., iPad) is capable of being taken anywhere and installing applications easily. This will facilitate the patients to play games anytime and anywhere without the need of professional help. In particular, the proposed game is incorporated with four tasks, which are specially tailored for hand exercise to enhance "dexterity of hand movements" and to correct "micrographia". Cueing trainings are integrated in these tasks to treat "bradydinesia" and "freezing" symptoms. The player's behavior data during each game session are captured and uploaded to the game platform server. These data are further analyzed to evaluate the

effectiveness of rehabilitation. Suggestions will be made for the patients and clinicians to track disease progression and adjust rehabilitation plan.

II. Related Work

Some commercial training games and game devices such as Wii have been adopted to facilitate physical therapy for PD patients. In [13], the authors conduct a pilot study on the commercial games based on Wii fit with a balance board for PD rehabilitation. The study shows that the home-based training programme integrated with visual feedbacks could help to improve the PD patients' abilities of static and dynamic balance and mobility. However, as commercial games and devices are not specially tailored for PD rehabilitation, they can be too challenging for PD patients, and may pose safety concerns during usage.

Some video games have been specially designed to fulfill the requirements of PD rehabilitation. In [9], a computational architecture based on the EyesWeb open software platform [16] is developed. Several modules are designed to be integrated in the architecture, such as analyzing and recognizing the PD patient gestures, generating real-time multimedia feedbacks, designing real-time therapeutic exercises adapted to the PD patients, and therapy progression evaluation. Some exercises (e.g., asking the player to paint using his or her body) are developed for evaluation purposes. A preliminary study is conducted on a male and female PD patient. The study shows that the exercises are able to generate aesthetically resonant feedbacks in PD patients and encourage them to persist through further rehabilitation.

An interactive multimedia system for PD rehabilitation is developed in [15], which is based on two physical therapy techniques -- multimodal sensory cueing [17] [18] and the BIG Protocol [19]. It focuses on the symptoms associated with *akinesia*. In the system, patients are asked to complete

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movement related tasks by controlling their avatars, which are mapped in the screen through capturing the location of patients' hands, feet, and torsos with a 10 near-infrared camera Motion Analysis System. Visual and auditory feedbacks are provided based on the accuracy and timing of the movements.

In [10], the authors propose to develop a medical game system for PD diagnosis and management. The system aims to assess patients' steadiness when traversing through the game environment and tremor at rest. The Novint Falcon Human Interface Device is used to record players' movements. The system is designed to provide force feedbacks to guide patients. However, due to the heavy requirement of Novint Falcon on hardware and other issues (e.g., accuracy measurement is difficult to achieve), the system implementation is rather difficult as stated by the authors.

In [11], the authors design and implement a collection of five mini-games (WuppDi!) to improve the memory and motion abilities of the PD patients. The mini-games require a complicated setup. Assistance from healthy people is recommended to ensure balance and stability of patients. A field study is conducted with 13 PD patients to explore their experience in terms of game contents, game play, and motion. In [12], the authors improve WuppDi! from the aspect of automatic personalizing game difficulty for each patient.

It can be noticed that though some thought-provoking works have been conducted on the aspects of game-based PD rehabilitation, the high cost, complicated setup, specific requirement of devices and particular design for rehabilitation also limit the large scale of their use. The commercial training games and devices are not suitable for PD rehabilitation either as they are too challenging for the patients. In view of this, we design and implement a tablet based game tailored for PD rehabilitation for patients in a convenient way.

III. The Pumpkin Garden Game Platform

To motivate the PD patients to persist in rehabilitation exercise over the long run, we have designed and implemented a tablet-based game platform -- the *Pumpkin Garden*. It consists of a virtual farming game, which is integrated with four tasks specially designed for the motor and cognitive rehabilitation exercise, and cloud-based data analytics to track the effectiveness of patients' rehabilitation progress.

The Design Approach

Evidence-based design (EBD) is adopted in the design of the proposed game. EBD is a field of study emphasizing the influence of credible evidence on design. This design approach is popular in healthcare to improve patient and staff well-being, patient healing, stress reduction, and safety. Four major steps are involved in EBD, as follows:

- Review existing research literature, and then select significant findings and recommendations;
- Match the selected findings with data gathered from field visits, survey results and domain experts;
- Predict the outcome of design decision;
- Track positive outcomes for design implementation.

Following the EBD approach, after a comprehensive review on current PD rehabilitation research works, we have gained knowledge on PD patients' symptoms and treatments. For example, many PD patients suffer from writing difficulties, such as lack of legibility and micrographia (i.e., characters are written in tiny size unintentionally). Rehabilitation for these symptoms include in-hand manipulation exercises, eye/hand coordination exercises, and graded individual finger movement exercises. With such a kind of detailed understanding, we conduct a feasibility and risk analysis of designing a computerized game for different PD symptoms. The analysis results are shown in Table 1 and 2.

	Significance	Effectiveness	Novelty	Data
Tremor	Medium	-	High	Most
Bradykinesia	Medium	Most	Low	Most
Rigidity	Medium	Some	Medium	Few
Balance	High	Some	Medium	Few
Walking	High	Most	Low	Most
Arm/Hand	Medium	Some	Medium	Some
Speech	Medium	Some	Medium	Some
Cognitive	Low	Few	High	Some
Dual Tasking	Low	Few	High	Some

Table 1. The feasibility analysis of computerized PD rehabilitation

	Lack of Valid Reference	Possibility of Failure	Possible Controversy	Extra Clinical Involvement
Tremor	High	High	High	High
Bradykinesia	-	-	-	-
Rigidity	Some	-	-	High
Balance	Some	-	High	High
Walking	-	-	-	-
Arm/Hand	Some	-	-	-
Speech	Some	-	-	-
Cognitive	High	-	High	High
Dual Tasking	High	-	High	High

Table 2. The risk analysis of computerized PD rehabilitation

After a cost-effectiveness consideration, we design four rehabilitation tasks specially for hand exercise for the rehabilitation of “dexterity of hand movements” and the correction of

micrographia. Furthermore, we also integrate cueing training for freezing in the proposed game, wherein cueing is widely used for PD rehabilitation. Freezing is one of the symptoms that most PD patients suffer in daily lives. It can be dangerous in some circumstances [20] as it can happen anytime such as during speaking and walking. Most of current cueing training for PD rehabilitation are for movement symptoms, which is not suitable for freezing as it is related with cognitive degeneration. In the proposed platform, we apply cueing training for both bradykinesia and freezing.

The Framework of Pumpkin Garden Platform

As shown in Figure 1 we design a tablet based game platform -- Pumpkin Garden to motivate the PD patients to have daily rehabilitation exercise.

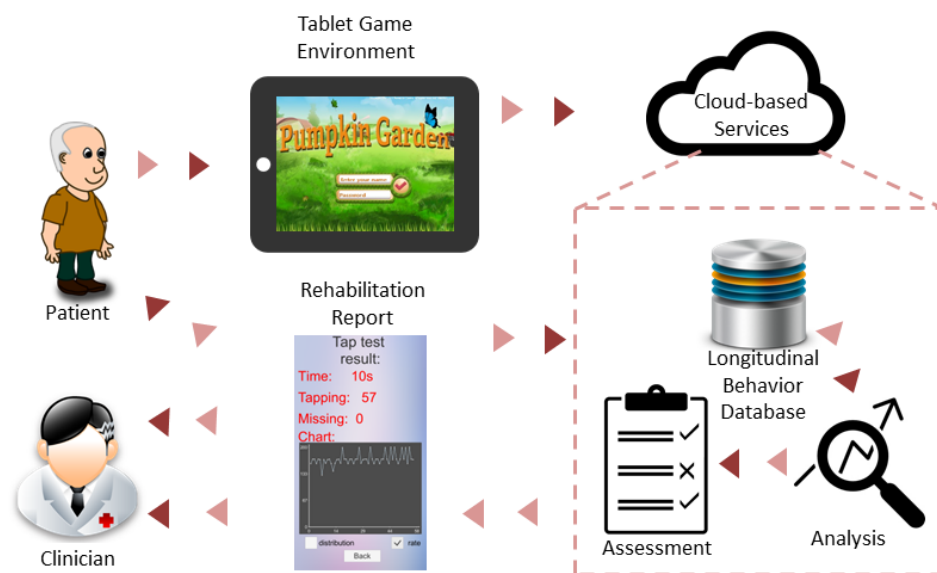


Figure 1. The conceptual framework of Pumpkin Garden

In particular, a patient can start the game anytime and anywhere. After the patient logs to the game, his profile and historical playing data will be analyzed for personalization to calibrate the game difficulty to suit his physical and cognitive conditions. The length of exercising will also be suggested to him. The patient's in-game behavior data will be captured and stored in the longitudinal behavior database to form his personal playing trajectory. After the patient completes the game, his behavior data will be analyzed and suggestions to the player according

to the analysis results will be made. The data stored in the database will be further used for long-term behavior analysis.

The Designed Game

We currently design four tasks for PD rehabilitation. The four tasks are *weed clearing*, *watering*, *pinching*, and *pumpkin harvesting*. The interfaces of the game and the tasks are shown in Figure 2. The game is currently implemented on the iOS system.



(a) Login



(b) Rehabilitation exercise selection



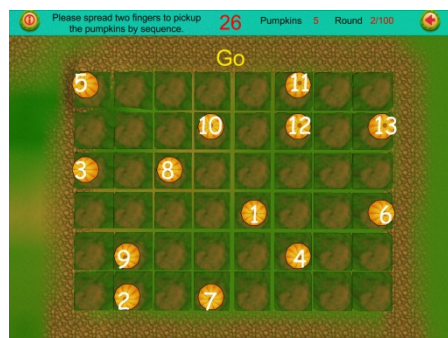
(c) Weed clearing task



(d) Watering task



(e) Pinching task



(f) Pumpkin harvesting task

Figure 2. Interaction designs for PD rehabilitation

More specifically, after a player logs in to the game through the portal shown in Figure 2(a), the game interface is presented to the player as shown in Figure 2 (b). The player's goal is to take care of the pumpkin garden by completing the four tasks in each game session. The duration of each task is through personalized setting. The details of the four tasks are illustrated as follows.

- Weed clearing: As show in Figure 2 (c), the patient is asked to clear the weeds by using a finger from each hand. Some barricades (i.e, flowers) exist among the weeds. The patient is supposed to clear weeds without touching flowers while moving the two fingers synchronously. These barricades are integrated in the game to simulate one of the freezing situations – a door-way or an obstacle in front of the PD patient. “Rhythm” is provided as the cueing technique in the game to help the patient to clear weeds fluently.
- Watering: As shown in Figure 2(d), the watering task requires the patient to move a finger in circle to drive the waterwheel to water the farm. There is a random pattern shown over the waterwheel, which serves as cues for the patient. Similar to the weed clearing task, music and visual hints are also adopted as cues and “turning around” in freezing situation is integrated in the task design.
- Pinching: As shown in Figure 2(e), in this task, the patient needs to cut off the leaves on the stems by using two fingers from one hand to simulate the action of pinching the leaves. Initially, there is one leaf appearing on a random position. After cutting it off, another will appear. Laser point is designed as cues, and dual-tasking in freezing situation is taken into consideration in this task.
- Pumpkin harvesting: As shown in Figure 2(f), in this task, there will be a random number of pumpkins to be harvested in the farm, and each pumpkin is labelled with a number. Similar to the pinching task, the patient is asked to collect the pumpkins using two figures from one hand, just like scissors, to collect the pumpkins following the

number sequence. If the number sequence is not followed, a message will be shown to the patient to ask him to correct errors. Visual cues are integrated in the task design, and dual-tasking and cluttered floor in the freezing situation are taken into account in the task.

III. Conclusion

PD is the second most common neurodegenerative disorder (after Alzheimer's disease) in Singapore. There is no cure found for PD until now. Rehabilitation plays an important role in delaying disease progression and improving the quality of living of the PD patients. Though video games have been found to be an alternative for the traditional rehabilitation means to encourage the PD patients to persist in rehabilitation exercises, the high cost of devices and the difficulty of playing the games without professional accompanies hinder the large scale of use. In view of this, we proposed a tablet based game platform -- Pumpkin Garden. The platform is built upon tablet devices, which make it possible for the patients to have rehabilitation exercises conveniently. Following evidence-based design, we have designed four tasks for the rehabilitation of the dexterity of hand movements, the correction of micrographia, and the rehabilitation of cognitive functions. Multiple cueing training technique (e.g., rhythm, music, visual, and laser points) and freezing situation (e.g., door-way, obstacle, turning around, dual-tasking, and cluttered floor) are integrated in the game design. The patient's in-game behavior is collected and the assessment of rehabilitation effectiveness is made. Suggestions are sent to the clinicians for necessary action, such as the adjustment of rehabilitation plan. In the future, we will consider the design of more tasks for PD rehabilitation. The study on the effectiveness of the proposed platform in PD rehabilitation will also be performed.

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