



# Development of Dual Cognitive Task Virtual Reality Game Addressing Stroke Rehabilitation

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## ABSTRACT

Components of stroke rehabilitation requires the input of dual cognitive tasks, which involves the multitask of both motor and cognitive skills simultaneously. An individual who had suffered a stroke may have problems executing dual cognitive task. Rehabilitation can help to improve the function of dual cognitive tasking. Games have been used for rehabilitation intensely. Virtual reality games have been acknowledged to assist the stroke patient in the rehabilitation process. However, stroke rehabilitations require special virtual reality game design for the patient to perform the dual cognitive task. A study has been conducted to determine the criteria and components that are directed for dual cognitive task for patients with stroke. The information was gathered through literature review and expert opinion from both the game experts, rehabilitation physicians and therapists. This paper will discuss the development of the virtual reality game incorporating dual cognitive task for stroke rehabilitation based on the principles and elements that has been identified. The focus of the study is to develop a virtual reality game on dual cognitive task for stroke patients that combine all the game elements, game type, virtual reality environment and also game theory for dual cognitive task rehabilitation. The adoption of the correct rehabilitation elements and principles in the design and development of a virtual reality game addressing dual cognitive task will be able to assist the stroke patient in the rehabilitation process.

## CCS Concepts

• Human-centered computing → Interface design prototyping

## Keywords

serious game; stroke rehabilitation; virtual reality; dual cognitive task;

## 1. INTRODUCTION

Recently, Virtual Reality (VR) has been used by many researchers and clinicians as a new technology for innovative rehabilitation treatments in cognitive and motor domains [1]. The advancements in technology enable more games to be produced

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[2], with VR game as one of the games that has great impact on its player. Enjoyment through games creates the experiential quality [3] and develops the cognitive ability in the players [4], [5], [6].

The use of the interactive three-dimensional (3D) virtual reality game environment for rehabilitation requires minimal assistance from therapist to facilitate patients to recover their body function especially in dual cognitive task problem [7]. Creating a virtual reality 3D games for the dual cognitive task stroke rehabilitation require many considerations such as game elements, game theory and game genre. Moreover, a high attention must be given on the ability of the stroke patient to use the virtual reality equipment when designing a game.

This paper will discuss the development of a virtual reality game to assist rehabilitation of stroke patients addressing dual cognitive task. The development is based on the data collected earlier [8]. The development was conducted with collaboration with the stroke rehabilitation multidisciplinary team.

## 2. DESIGNING VIRTUAL REALITY GAME

The development of the virtual reality game includes the conceptual framework design, storyboard design and incorporating the clinical elements to fulfill the goals towards stroke recovery.

### 2.1. Conceptual Framework

The conceptual framework of this study consists of several components such as the stroke patient needs, virtual reality elements and game elements, game mechanic, game theory and the therapy technique [8]. The framework is developed based on expert review and interviews as well as the literature review.

The goal to develop a VR game for rehabilitation is to motivate and to sustain the patient's interest. Nevertheless, there are some challenges faced in designing VR game for rehabilitation purposes. The game should utilize inexpensive and safe equipment for the stroke patients to use at home. Therefore, the equipment should be light and will not be a burden to the patient's function.

The framework also focuses on adventure as the game genre for this VR game which offers exploration as the main attraction. The common cognitive skills identified in a good adventure game player includes the ability to think, to be creative and have the element of curiosity to explore.

For the game theory, the Prisoner Dilemma game theory is found suitable for this type of game. This theory uses decision- making assist stroke patients in redeveloping cognitive skills through decisions and strategies of how to successfully play the game. At the end of the game, a displayed the game score will shoe their achievement, an important element to measure progress and outcome.

The element of the game mechanics for stroke rehabilitation is based on the interactive cognitive motor training (ICMT). ICMT is commonly used in conventional therapy whereby motor skills training is combined with that of cognitive tasks.

There is great potential on the use of virtual reality environment to augment stroke rehabilitation through gamification. The framework described [8] emphasises on off the shelf or inexpensive equipment, non health risk to end users and carers, and games designed to comply with ICMT with appropriate challenges, reward and scoring system. All these elements will potentially give motivation with added goal orientation and meaningful play.

## 2.2. Storyboard

Storyboard is designed to fulfill the elements of the framework. The design of the game will focus on the game elements, game mechanics, game theory that is suitable for patients with stroke to do dual cognitive tasks. Figure 1 below showed the storyboard of VR game for dual cognitive task. From the storyboard, the game will have the home page, three levels of VR game which have different environment and instruction and also the score that they will get after finish playing the game.

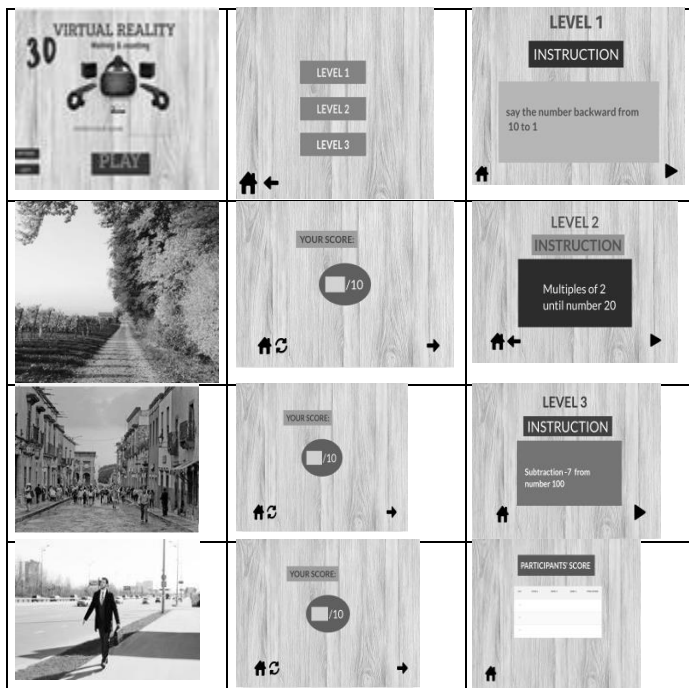


Figure 1. Storyboard of virtual reality game

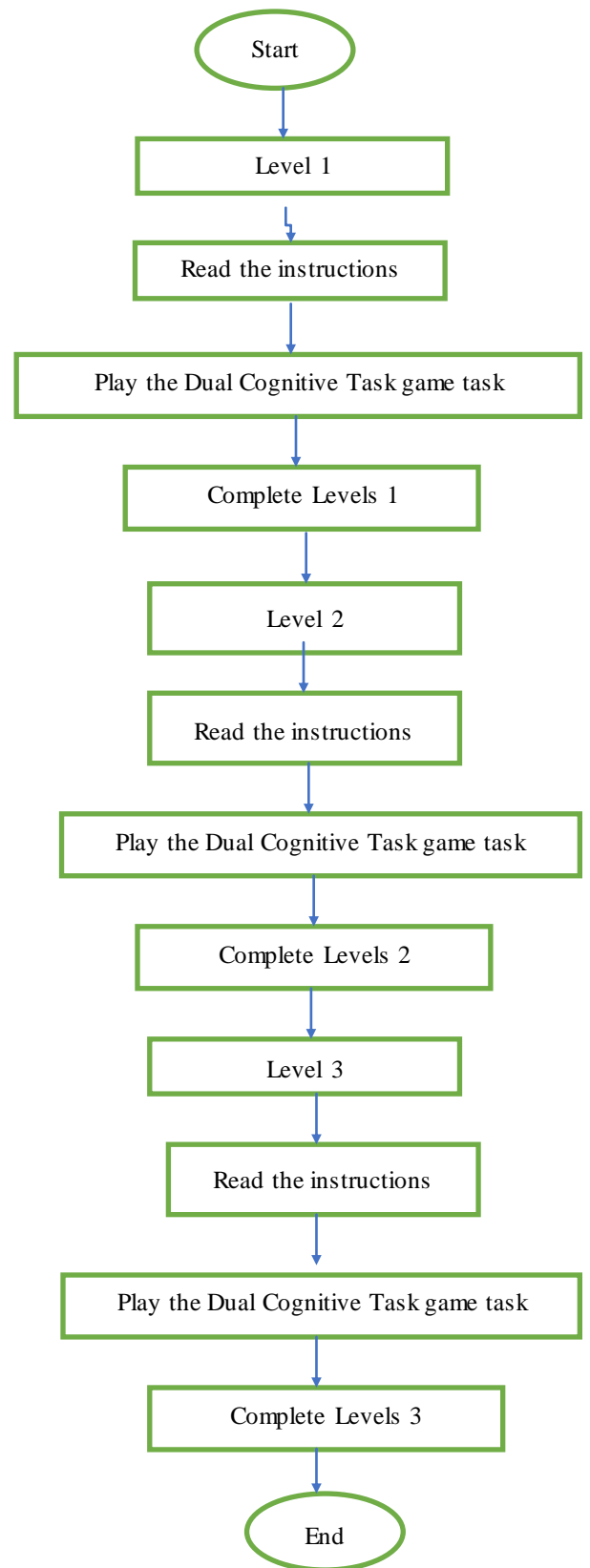


Figure 2. Flowchart of virtual reality game on dual cognitive task for stroke rehabilitation

The game was designed to be simple and easy to comprehend. It does not require high cognitive function other than what is required for the rehabilitation purposes. The game begins with the game level 1. There are three levels, with different VR environments and task. The game level is based on patient's capability. Stroke patient needs to understand the instruction before playing the game. The game consists of the dual cognitive task that the patient must accomplish. For this game, a stroke patient needs to walk while counting the numbers. Upon completion of the game, therapist will summarize the score for every level. This straight forward flow is repeated for all levels (Figure 2).

### 3. DEVELOPMENT OF VIRTUAL REALITY GAME

#### 3.1. Cognitive and Motor Impairment Post Stroke

The actions of simultaneously doing both cognitive and motor task is termed "dual cognitive task" [9,10,11]. The execution of dual cognitive task can be a challenge for individuals with stroke. The demand of simultaneously completing a task with both cognitive and motor skills can be high in this population, and may not be performed well. Unlike stroke patient, dual cognitive task, such as walking is easy for a normal and healthy person, as walking becomes an automatic task. The risks of fall are also increased with dual tasks in older adults [10]. Researchers have investigated that the nature of cognitive tasks will influence and reduce walking speed in dual-task condition [11].

The use of VR games as an augment to stroke rehabilitation have the potential to improve the functional outcome [11]. Inexpensive virtual reality gear is currently readily available in the market. As per discussed earlier, the game will be suitable for patients with stroke as it was designed to be low health risk. Furthermore, the game incorporates all the game elements such as multiple levels, game challenges, reward and score and also meaningful play through feedback. These game elements will motivate the patient to continue doing the rehabilitation and thus, gives a positive impact on them by improving their dual cognitive ability.

The virtual environment created will be of immersive virtual reality. The dual task activities will be walking while counting the numbers. This is the dual task that is proposed by the professionals managing stroke rehabilitation and also part of the conventional practice at the Department of Rehabilitation Medicine at Universiti Teknologi MARA Medical Specialist Centre in Sungai Buloh, Malaysia.

#### 3.2. Challenge in Virtual Reality Game

The use of VR for physical health is still new in the rehabilitation arena. Studies have supported the use of VR in rehabilitation addressing dual cognitive tasks for patients with stroke [12,13]. One of the advantages identified was the capacity of VR environment to immerse an individual into an environment that conventional clinical settings could not fulfill.

However, challenges for stroke patient when dealing with VR apparatus have been identified. Some apparatus may become a nuisance to the patient especially if there are wired to the head or body. Hence, it is of upmost important that the designer take into account the hardware to yield low health risk and not be burdensome to the stroke patient [14,15].

In the development of this virtual reality game, the HTC Vive virtual reality headset has been chosen as the VR device for the game, as shown in Figure 3. The set gives fully immersive first experience to the user. It creates a 15' X 15' virtual world borderless boundary for the player to move around when playing the game. There is a system to warn the player of the boundary, therefore the player is safe in the virtual environment. The virtual world can also be created in a dedicated room for the rehabilitation session. The setting up of this environment is far cheaper than setting up a multisensory room for the rehabilitation process. Nevertheless, for a home use, user can also purchase any cheaper VR box to play and use on their phone.



Figure 3. Oculus HTC vive virtual reality headset

#### 3.3. Virtual Reality Game Element

The game design for the dual cognitive task rehabilitation incorporates levels of challenge, reward and score, motivation and meaningful play. The game is designed to have three levels with varying challenges. Each level increases its difficulty. As the player play the game, he/ she will move on to the next level depending on its score. This also denotes the capability and improvement of the stroke patient during rehabilitation.

The game play involves the player/ stroke patient counting backwards while walking. Counting and walking are the two cognitive tasks that are being practiced. For Level 1, stroke patient needs to say the number backward from 10 to 1 while walking. Meanwhile, for Level 2, they need to say the number in multiple of 2 until number 20. Finally for Level 3, the stroke patient needs to say the number in subtraction 7 from number 100. All these are shown in figure 4,5,6 and 7 below. In order to know whether the game has a meaningful play, the stroke patient needs to answer the questionnaire after playing the game.

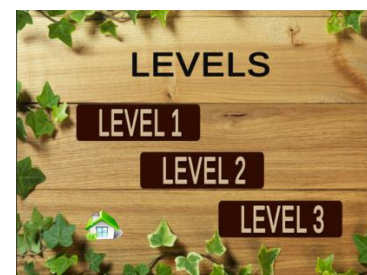


Figure 4. Levels in VR game

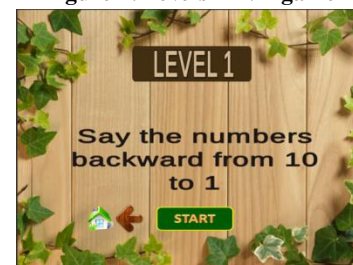


Figure 5. Instruction for Level 1



Figure 6. Instruction for Level 2



Figure 7. Instruction for Level 3

### 3.4. Virtual Reality Environment

The game genre selected is the adventure game. In the game, the stroke patient needs to do backward counting the numbers while walking on the flat surface with the help of the therapist. While walking, the patient will be experiencing a different VR environment. The different VR environment also posed as different level of challenges in the game.

For Level 1 of the game, the stroke patient needs to count the numbers in a quiet VR environment. For Level 2, they need to count the number in a noisy VR environment. There will be people talking in the environment. This adds the complexity for the level in terms of the cognitive processing. Level 3 increases the complexity. In this level, the VR environment becomes busier. The stroke patient needs to walk in a noisy VR environment which has the sound of many people talking and the sound of the vehicle while counting the numbers. All the different levels of VR environments are show in figure 8, 9 and 10 below.



Figure 8. Level 1 environment



Figure 9. Level 2 environment



Figure 10. Level 3 environment

### 3.5. Virtual Reality Game Theory

For the game theory, the Prisoner Dilemma game theory is used. This theory is responsible to guide the stroke patient to make decisions and thinking of the game strategy. In this game, the strategy is the cognitive strategy on how to accomplish the required task that is counting while walking [16,17,18]. At the end of game, the game score will be displayed as shown in figure 11 Therapist upon completion of the task will verify the game score.

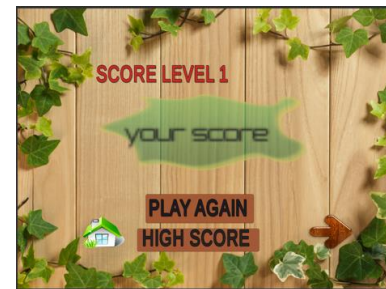


Figure 11. Score Level

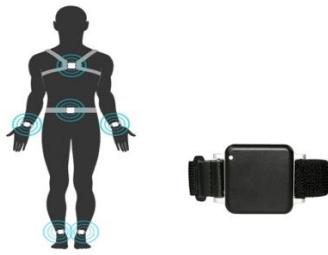
In addition, for the rehabilitation purposes, Interactive Cognitive Motor Training (ICMT) technique is being applied. ICMT requires stroke patient to walk during counting, as part of performing the game play. This technique combines the motor and cognitive task together.

### 3.6. Evaluation

Six stroke patients will be selected to evaluate the usability of the game. The selection of participants will be done with the help of the Rehabilitation Physician and therapist. The willing participants will go through the selection process which consists of pre- and post-assessment. Ethics approval has also been granted for the clinical usability evaluation and assessment from the institute's Research Ethics Committee (Ref: 600-IRMI (5/1/6) REC/20/18)

During the pre-assessment, participants will answer questionnaire about their VR game knowledge and their vital sign will be assessed and recorded. They must also go through the attentional skills test and balance performance assessment with a therapist. These tests will be done using the APDM mobility lab (Figure 12). This will calculate their walking speed and number of steps.





**Figure 12. APDM Mobility Lab**

After completing the rehabilitation session using the VR game, the participant will answer the usability questions about the use of virtual reality game for rehabilitation and measuring their satisfaction level towards the game. Besides these information, therapist will also be doing the recoding of the assessment score when using the VR game for rehabilitation. The finishing time and the number of failures to perform the dual cognitive task will be recorded. The result obtained will determine the usability and suitability of using the VR game for dual cognitive task rehabilitation for stroke patient.

#### 4. CONCLUSION

As a conclusion, this 3D virtual reality game, which focuses on walking and counting as the dual cognitive task, is a promising rehabilitation tool for stroke patient. The game was designed based on sound information gathered from literature, and data from interviews and questionnaires and various considerations. The game incorporates the VR device consideration that will not become a burden to the patient and yet affordable for home use. It uses strategy game genre which emphasizes on game storytelling for creating the VR environment. The 3 levels VR environment gives different difficulty levels and thus creates the game challenge. It also applies the Prisoner's Dilemma theory and ICMT technique for the game mechanic. This VR game development is a result of a thorough study from the computer science, health sciences and medical field. VR game can be seen as a rehabilitation tool that could motivate patient to continue doing the therapy even when they are at home. This is hoped to expedite their recovery process.

#### 5. ACKNOWLEDGMENT

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