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# Virtual Environment Design Guidelines for Elderly People in Early Detection of Dementia

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***Abstract*—**Early detection of dementia by testing the spatial memory can be applied using a virtual environment. This paper presents guidelines on how to design a virtual environment specifically for elderly in early detection of dementia. The specific design needs to be considered because the effectiveness of the technology relies on the ability of the end user to use it. The primary goal of these guidelines is to promote accessibility. Based on these guidelines, a virtual simulation was developed and evaluated. The results on usability of acceptance and satisfaction that are tested on young (control group) and elderly participants indicate that these guidelines are reliable and useful for use with elderly people.

***Keywords*—**Virtual Environment, spatial memory, design, guidelines

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## I. Introduction

DEMENTIA is associated with loss of brain function that occurs mostly in people over the age of 65. This serious illness needs early diagnosis if medical treatment and healthcare services are to be deployed in time, before the neurones degenerate to a stage beyond repair. Memory loss is therefore a major concern for elderly people. Reference [1] examined on assessing navigational performance in people with early AD and MCI patients using a virtual reality environment. A study by reference[2] shows that spatial memory in older adults can be investigated using virtual reality technology.

Virtual environments allows a more or less complete functionality without requiring all the functions to be located in the same physical space to an integrated workspace [3] as well as the interactive and virtual image displays enhanced by special processing to feel the sense of presence in a synthetic space [4]. Virtual reality technology has been applied in various domains including education, entertainment, engineering, medicine and healthcare. Revolutionary health care applications have also been shown to be highly effective in medical therapy, visualization of databases, medical education and training and also as a psychotherapeutic tool. Furthermore, it is often used for treatment for a wider range of anxiety disorders. Virtual reality technology is a promising tool which can be applied in developing a specific application for early detection of dementia; this may not only help with future treatment but will also help with the planning and care services needed for these people.

However, for these tools to be effective, the virtual environment must be usable and reliable for elderly people. One of the major factors in the slow uptake to assist technologies for persons with dementia is the usability of the user interface [5]. This paper discusses specific guidelines on the design and development of a virtual environment for people with dementia.

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## II. Guidelines

Elderly people who grew up without the benefit of having computers may feel that computers are not meant for their use or relevant to them. The technological resolution was developed before the growth of this generation [6]. Research [7] concludes that elderly people find it difficult to use standard interface compare to young. As a conclusion, for the full potential of technology to be useful for these people, the needs and requirements must be considered in designing the virtual environment. Moreover, this research focuses on early detection of dementia and requires participants to walk through the virtual environment and finish the tasks, these specific guidelines are necessary for participants to be motivated to take part in the simulation.

### *A. Levels of Difficulties*

The ease of learning in initial stage and able to master the other stages should be considered in designing successful computer games [8]. The increasing level of difficulties in most games gives the players' motivation of challenge to adapt their specific skills [9]. In this application, there are five different levels of difficulty which range from easy to complex. The levels of difficulty depend on junctions, paths and target destinations which users have to achieve. Additionally, dummy destinations were added to make the path more complex and difficult. This implementation allowed us to investigate users' task performance in each level. Table 1 summarizes the junctions and turns they had to make to get to the destinations.

TABLE I
SUMMARY OF THE JUNCTIONS AND TURNS IN THE SIMULATION

| *Levels* | *Junctions and Turns* |
|---|---|
| Level 1 | 1 |
| Level 2 | 2 |
| Level 3 | 3 |
| Level 4 | 4 |
| Level 5 | 5 |

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### B. Different Routes

Different versions are routinely used in experimental psychology. In this application, we implemented different layouts and routes for each module: VRPark and VRGames. Both scenarios are generally in a virtual garden. VRPark has the target destination of a park such as playground, picnic area, art gallery, park squares and mini garden. For the second module, VRGames has the target destination to outdoor games such as giant chess, giant board games, lawn bowl mini golf and picnic area. Both modules have the same numbers of landmarks (see Table 2), and levels. In addition, VRPark's path is mirrored to VRGames' path. Here, we present two different path styles to test the efficiency and effectiveness for the experiments (see Figure 1).

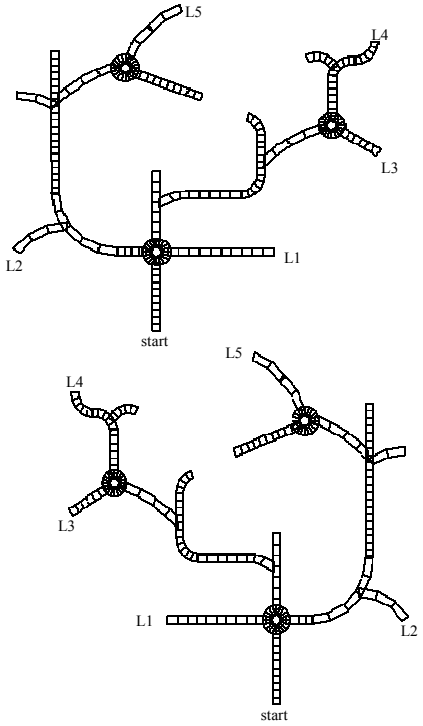



Fig. 1 (a)Path in VRPark (b) Path in VRGames

### C. Linking of Psychological Theories

This research embeds the psychology theories into the design and development of the simulation. The theories embedded are behaviourism, cognitivism, constructivism and error based learning. Reference [10] in their paper summarizes the learning theories as below:

1. *Behaviourism*
   - the concept of repetition & reward.
   - repetition in a game and receiving rewards
2. *Cognitivism*
   - integrating learning and game experience to build intrinsic motivation
   - game experience that integrates learning and play engages a discovery process.
3. *Contructivism*
   - offer game challenges to solve problem

Errorless learning is one of the more successful techniques used in rehabilitating people with memory disorders, especially those with a more severe impairment [11]. Errorless learning can be defines as presenting information across acquisition trials in such a way that the learner is prevented from making errors, learning exclusively by repeated exposure to correct information [12].From the theories above, the simulation had successfully embedded these theories in the design and implementation as summarize in Table 2.

TABLE II
SUMMARY OF PSYCHOLOGICAL THEORIES AND ITS IMPLEMENTATION

| *Theories* | *Implementation of VReDD* |
|---|---|
| Behaviorsm | • Training Module in understanding the movement,e.g : using the cursor keys.<br>• Overall scores of the performance as rewards. |
| Cognitivism | • Simple and structured interface and contents. |
| Constructivism | • Different type of modules and scenarios.<br>• Five different levels from easy to complex. |
| Errorless Learning | • Repeat the exercise of reaching the target destination three times by following the red ribbon attached to the path |

### D. Landmarks

Landmarks are useful to find directions and any communication about space[13] .They can be divided into two major categories: geometric and object landmarks. Geometric landmarks are the salient features of the environmental construction, while object landmarks are the salient objects within the environment which can be easily distinguished from the background, such as a streetlamp or buildings [14]. In order to further investigate spatial memory in navigation, this study reduces landmarks. Table 2 shows all the landmarks used in the application for all levels. There are no maps in this application to help users and signs are hidden and can only be seen in training phase. This is to test users' spatial cognition with limited landmarks.

TABLE III
ALL THE LANDMARKS USED IN THE APPLICATION FOR ALL LEVELS.

| *Landmarks* | *Numbers of Landmarks* |
|---|---|
| Statue | 1 |
| Trees | 94 |
| Benches | 26 |
| Fences | Completely around the path |
| Junctions and turns | 18 |
| Dummy destination | 6 |
| Buildings | 39 |

### E. Data Collection

Data were collected automatically during the testing phase in real time. There are five attributes needed to diagnose early detection of dementia: correct path, incorrect path, correct sequences, incorrect sequences and time.

1. Path

During testing, users are allowed to move freely to the target destination. All the movements are captured and recorded for data analysis.

2. Path Sequences and Path Squares

Users are required to reach the target destination in the

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correct path sequence. The data from path-tracking will show correct sequences, incorrect sequence, correct squares and incorrect squares. Path squares is an underlying grid unseen by participants. While users moved along the path, the unseen grid will be tracked and recorded. This will ensure all the movements are captured to be analysed.

3. Timing

During testing, the amount of time taken to complete the journey from the starting point to the target destination was recorded.

4. Score

Scores are then calculated based on path sequences and path squares. The scores show the percentage of performance done by users.

### *F. Collision detection*

Collision detection in virtual environment is very important because it determines how close you can get to the 3d object. It will automatically stop the movement before it can collide to the object. In this application, users are only allowed to move on the path without going off to the grass or elsewhere. The main reason for this collision detection is to avoid disorientation for the users. Boundaries were programmed in this application to prevent elderly people from navigating beyond the path or route given.

### *G. Training module*

Training module is essential especially when it involves elderly people who may be less proficient at computer use than younger people. In our simulation, we have implemented a training module called VR Practice where users have the opportunity to practice with the arrow keys using the keyboard. The four arrow keys: up, down, left and right are used to navigate through the virtual environment. This practice helps them to use the application easily.

### *H. Simple and Structured Interface*

The simplicity of this virtual environment is essential when use to study spatial memory for navigation. A structured and simple interface is important on understanding the interactive process so that user will fully concentrated on task [5]. Simple and relevant graphics should be used in the designs and avoid decorative animation and pictures, wallpaper patterns and flashing text [15] as well as icons should also be familiar to the users [16]. The font sizes of a site should be 14 points or more and have very clear headings because of a general declines in visual acuity among elderly persons [17].

### *I. Scenarios*

The outdoor environment seems to be one of the opportunities for elderly people to be physically active, to have contact with nature and to meet with friends and neighbours [18]. Outdoor activities is hard to perform for these elderly people due to the combination of increasing frailty in late life and barriers in the environment, going outdoors [19]. As an alternative to safe and healthy issues, a virtual environment seems to be one of the best solutions to investigate on spatial memory. The scenario was created like real life environment. Scenarios chosen for this application are in the park or an open environment with mainly trees and benches and surrounded with tall buildings and blue sky.

## III. Development of VReDD

### *A. Hardware and Software Requirements*

The development of this virtual environment requires a high specification of hardware. In this development, the hardware consists of a Pentium-based computer with NVIDIA graphic cards of 512mb memory, 4mb RAM and Intel Core Duo processor. Modeling was done using Maya to create models and scenes. Then the scenes are exported to Virtools, a 3D authoring tool which handles all the programming that includes interactivity, setting and configuration. For analyzing and representation of the results, an information system was developed using Visual Basic.

### *B. Virtual Environment*

Virtual Reality for Early Detection of Dementia or known as VReDD consists of three modules: VR Practice, VR Park and VR Games (see Figure 2).

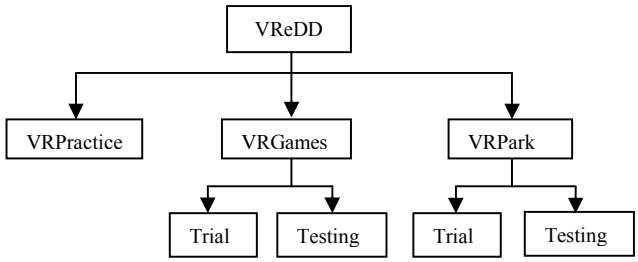



Fig. 2 Overview of VReDD

1. VR Practice

VR Practice is the training module. In this module, users are trained to use the four cursor keys with the red ribbon attached to the path.

2. VR Park

The scenario settings for this module are in a park. There will be five specific target destinations including playground, art gallery, garden, rest area and picnic area. Users will experience walking through a park in the city where there are tall buildings to be seen, trees all around and various other things (see Figure 3).



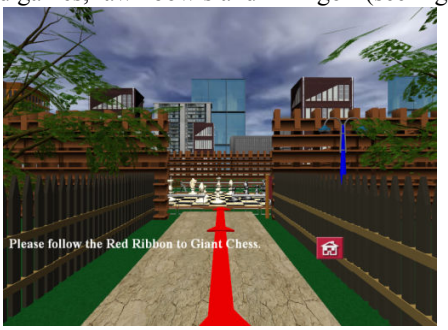

Fig. 3 (a) VRPark environment : Garden




Fig. 3 (b) VRPark environment : Gallery

3. VR Games

In this module, the location is surrounded by tall buildings and houses. Inside the park, there will be five different and specific types of giant games available, such as giant chess, giant board games, lawn bowls and mini golf (see Figure 4).



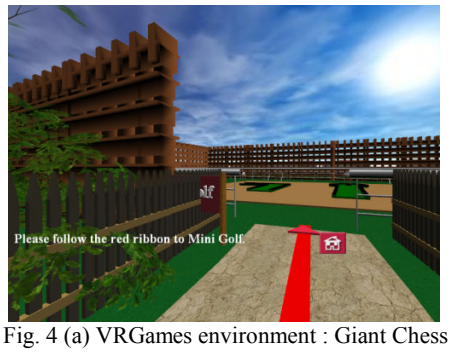




Fig. 4 (a) VRGames environment : Giant Chess
(b) VRPark environment : Mini Golf

*C. Procedure in VReDD*

Figure 5 represents a procedure done in VReDD. First, users' information will be recorded in the system. A unique user ID will be given to each user. Then, in the VR simulation, users will have the choice of using either VR Park or VR Games. The users were allowed to repeat the exercise of reaching the target destination three times by following the red ribbon attached to the path. Next, the user will be tested on their memorizing of the given path. All data will be collected and recorded during this phase. Lastly, all data will be exported to the system to be analysed.

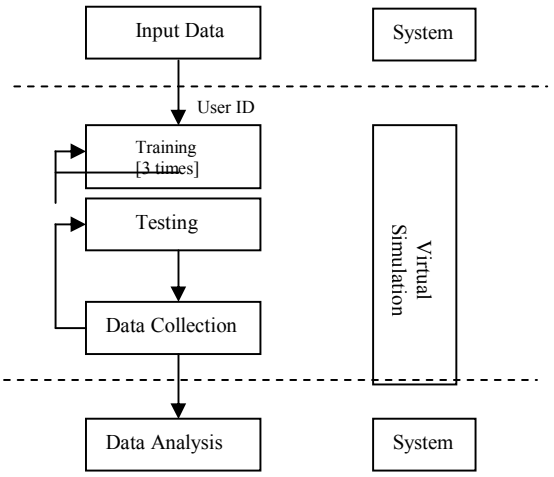



Fig. 5 Procedure in VReDD

## IV. Conclusion

To date, experiments have been carried out with young and elderly participants. A total of 31 elderly participants of ten males and twenty-one females from age 60 to 81 took part. In addition, 17 young participants have also been recruited for this experiment. The results from these testing sessions have produced positive results [12,13]. The guidelines presented here are essential in the development of a virtual environment for elderly with dementia in testing their spatial memory. The findings demonstrate that it is feasible to work in virtual environment with elderly people and the results also indicated a high level of usability in all categories evaluated.

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