Procedural Learning in Virtual Environments and Serious Games

Nor Nazrina Mohamad Nazry

Department of Computer Science
University of Sheffield

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Abstract

Virtual environments and serious games are a popular media used to fulfil a variety of purposes, including teaching and learning. The former are computer-generated environments that present three-dimensional spatial representations. The latter are games which fundamentally combine virtual environments and gamification, and are used for objectives other than pleasure and pure entertainment. Most recent works have investigated the effect of virtual reality technology on learners, sense of presence and so on. However, less investigated is the relationship between the achievement of learning objectives and the knowledge delivery methods utilised (knowledge representations and instruction modalities); or the effect of technology-enhanced learning on learner's mood after the intervention (and consequently, the learning) and whether there is any gender difference; or finally, the transfer of knowledge from virtual to the real world and its long-term retention; which are all elements investigated in this research.

Two studies of procedural learning were conducted to investigate the elements highlighted above. The first study investigated on the requirements of a three-dimensional virtual environment as compared to Google Street View, instruction modalities such as textual, phone and companion, and short-term memory to learn a new route. The findings show that the virtual environment is better than Google Street View according to users' experience and having a companion to the task is a better instruction modality for route learning. The second study focused on ritual learning that is the case study of the research. The study investigated on the efficiency of a serious game as compared to PowerPoint note, collaboration with and without a coach, memory recall between short and long-term period and gender differences. The findings indicate that the serious game is better than PowerPoint note according to users' self-reported score and having the coach improves users' learning efficiency and moods. Also, knowledge of landmarks representations remains longer in users' memory if learnt from the serious game and factual knowledge remains longer in users' memory if learnt with the coach. Considering gender differences, women feel that the task is more enjoyable if learning takes place with the companion, and they recall more landmarks than men, whereas men take less time to complete the task.

Apart from that, the ritual and navigation knowledge acquired in a virtual environment or a serious game can be competently used in reality, and it encourages users to remember more landmarks. The further findings from both studies also reveal that navigation in the virtual environment and serious game improve users' overall mood and happiness and women with improved happiness after the virtual training increase their learning performance. Also, younger players improve learning performance after learning in a virtual environment and serious game.

To sum up, virtual environments and serious games can be used as a delivery method for procedural learning, in particular for ritual learning as they induce enjoyment, create an interesting experience and stimulate learning performance. Both representations also encourage landmarks memorization. Also, collaborative learning, in particular with a coach, is always the best method to convey, share and understand the knowledge. Finally, women enjoy learning with a companion.

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List of Abbreviations

$2/3D$	Two/Three-dimensional
VE	Virtual environment(s)
GS	Google Street View
RW	Real world
TP	Text on paper
PI	Phone instructor
DC	Direct companion
USE	University of Sheffield Enterprise
$SatNav$	Satellite navigation
t	t-test
H	Kruskal-Wallis test
W	Wilcoxon test
U	Mann-Whitney test
SG	Serious game
PPT	PowerPoint note
NC	Novices Coach
NN	Novice Novice
ST	Short-term
LT	Long-term
M	Males
F	Females
$Exp.$	Experiment

Chapter 1

Introduction

Contents

This chapter provides an overview of the entire work conducted to date, and the motivations that have inspired the presented research, which investigates the use of virtual environments and serious games for procedural learning, in particular, when learning ritual procedures. The chapter explains, in brief, the case study considered, the research aim, the contributions to knowledge and the published material. Finally, a thesis outline is presented.

1.1 Motivation

Numerous studies have used simulations and virtual environments to complement and further support existing teaching methods. The findings from previous studies have indicated that in general learners' performances improve after a technology-supported session. Most recent works have investigated the effect of multi-sensory interactions and virtual reality technology on learners, their first hand experience, sense of presence and so on. However, less investigated is the relationship between the achievement of learning objectives and knowledge delivery methods utilised (knowledge representations and instruction modalities); or the effect of technology-enhanced learning on learner's mood after the intervention (and consequently, the learning) and whether there is any gender difference; or finally, the transfer of knowledge from virtual to the real world and its long-term retention; which are all elements investigated in this research.

Although virtual environments have long been used in the military and medical area, recent studies have shown considerable interest to utilise them in all spheres of learning, including learning a ritual procedure in Islam. As in the therapeutic area, some rituals have complex practices that require an excellent understanding of the procedure and good imagination to perceive them correctly. Previous studies have suggested that using a virtual representation to learn the Tawaf and Sa'ie[1] ritual in Hajj might help. However, the applications created to date have shown some weaknesses, such as an incomplete explanation on how to perform the ritual, or an insufficient three-dimensionality of the represented world, suggesting that more work is needed for a correct application of virtual environment for ritual learning.

1.2 Case Study

This research is sponsored by Ministry of Higher Education Malaysia and Sultan Idris Education University Malaysia. The Sa'ie ritual was chosen as the case study to be investigated, as it is one of the important rituals for millions of people that perform it every year in very crowded conditions. The correct execution of it can help prevent incidents. As such, in this research, some essential elements connected with learning procedure in navigation-based virtual environments were investigated, and the findings were applied to the case study (the Islamic ritual of Sa'ie).

Sa'ie can be defined as travelling back and forth seven times between Safa and Marwah[2] hills. It is an essential ritual (or *Rukun*) in Hajj, an Islamic pilgrimage to Makkah, Saudi Arabia. If its essential parts are not carried out, Hajj is considered invalid. The basic principles of the Sa'ie ritual are to navigate along the prescribed path correctly and also to perform specific actions at different points of the path. The actions are divided into two procedures: Conditions and Options (or *Sunnah*). While performing Sa'ie, pilgrims need to get familiar with reference points in the surrounding area, for example, green lights area and travel lanes. Moreover, Muslims believe that they will get special rewards from God by doing the Hajj ritual correctly. This ritual and its requirements are discussed in more detail in Chapter 3.

1.3 Research Aim

The broad research aim of the presented work is to investigate whether virtual environments and serious games can be used to learn ritual procedures. Six elements were investigated in depth as follows:

1. Knowledge representations in procedural learning
2. Optimal instruction modalities for learning navigation skills and ritual
3. Mood and learning in navigation-based virtual environment and serious game

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[1] or Sa'i
[2] or Al-Safa and Al-Marwah

4. Transfer of knowledge from virtual training to real world

5. Knowledge transfer in short- and longer term after virtual training

6. Finally, if there is any gender difference in any of the above.

1.4 Contributions to Knowledge

Below are the reported research findings obtained through empirical experimentation using a purpose built virtual environment and serious game, which were conducted to answer the six elements described above:

- A virtual environment is better than Google Street View for route learning according to users' experience

- A serious game is better than PowerPoint note for ritual learning according to users' self-reported score

- Having a companion to the task is a better instruction modality to learn a new route

- Having a coach improves users' learning efficiency and moods

- Navigation in a virtual environment and serious game improve users' overall mood and happiness

- Women with improved happiness after a virtual training task increase their learning performance

- The ritual and navigation knowledge acquired in a virtual environment or a serious game can be competently used in reality, and as compared to other visual representations, it encourages users to remember more landmarks

- Knowledge of landmarks representations remains longer in users' memory if learnt in a serious game (or virtual environment)

- Ritual learning with a companion improve women's overall mood

- Ritual learning with a companion decrease men's tiredness

- Women recall more landmarks than men

1.5 Published Material

Parts of Chapter 2, 3, 4 and 5 were combined to discover further results. The work is described in Chapter 6, and it is published in the Journal of Computers in Human Behavior as follows:

- N.Nazrina M.Nazry and D. M. Romano, "Mood and learning in navigation-based serious games", Computers in Human Behavior, vol. 73, pp. 596-604, 2017.

1.6 Thesis Outline

The thesis is organised as follows:

- Chapter 2 discusses a general literature review of learning, virtual environments and serious games
- Chapter 3 presents the case study of the research (Sa'ie)
- Chapter 4 describes the plan and findings of the first experimental study (Study 1) that investigated the choice of visual representations, instruction modalities and memory recall
- Chapter 5 explains the plan and findings of the second experimental study (Study 2) that investigated the choice of visual representations, collaboration, memory recall and gender differences
- Chapter 6 presents the findings of combined studies between Study 1 and 2
- Finally, Chapter 7 presents the research conclusions and its implications for teaching and learning, suggests fruitful avenues for further research and shows the self-reflections based on the research experience.